ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION

Showing the Operations, Expenditures
and Condition of the
Institution

FOR THE

YEAR ENDING JUNE 30, 1904

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1904.

SMITHSONIAN INSTITUTION,
Washington, D. C., February 27, 1905.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1904.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Hon. WILLIAM P. FRYE,
President pro tempore of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1904.

SUBJECTS.

1. Proceedings of the Board of Regents for the sessions of December 8, 1903, and January 27 and March 7, 1904.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1904.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1904, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1904.

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THE SMITHSONIAN INSTITUTION.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

Theodore Roosevelt, President of the United States.
(Vacancy), Vice-President of the United States.
Melville W. Fuller, Chief Justice of the United States.
John Hay, Secretary of State.
Leslie M. Shaw, Secretary of the Treasury.
William H. Taft, Secretary of War.
Philander C. Knox, Attorney-General.
Henry C. Payne, Postmaster-General.
William H. Moody, Secretary of the Navy.
Ethan Allen Hitchcock, Secretary of the Interior.
James Wilson, Secretary of Agriculture.
George B. Cortelyou, Secretary of Commerce and Labor.

REGENTS OF THE INSTITUTION.

(List given on following page.)

OFFICERS OF THE INSTITUTION.

Samuel P. Langley, *Secretary*.

Director of the Institution and Keeper of the U. S. National Museum.

Richard Rathbun, *Assistant Secretary*.

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons, other than members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1904.

The Chief Justice of the United States:

MELVILLE W. FULLER, elected Chancellor and President of the Board, January 9, 1889.

The Vice-President of the United States (vacancy):

WILLIAM P. FRYE, President pro tempore of the Senate, acting as Regent.

	Term expires.
United States Senators:	
SHELBY M. CULLOM (appointed Mar. 24, 1885, Mar. 28, 1889, Dec. 18, 1895, and Mar. 7, 1901)	Mar. 3, 1907
ORVILLE H. PLATT (appointed Jan. 18, 1899, Feb. 23, 1903)	Mar. 3, 1909
FRANCIS M. COCKRELL (appointed Mar. 7, 1901)	Mar. 3, 1905
Members of the House of Representatives:	
ROBERT R. HITT (appointed Aug. 11, 1893, Jan. 4, 1894, Dec. 20, 1895, Dec. 22, 1897, Jan. 4, 1900, Dec. 13, 1901, and Jan. 12, 1904)	Dec. 27, 1905
ROBERT ADAMS, JR. (appointed Dec. 20, 1895, Dec. 22, 1897, Jan. 4, 1900, Dec. 13, 1901, and Jan. 12, 1904)	Dec. 27, 1905
HUGH A. DINSMORE (appointed Jan. 4, 1900, Dec. 13, 1901, and Jan. 12, 1904)	Dec. 27, 1905
Citizens of a State:	
JAMES B. ANGELL, of Michigan (appointed Jan. 19, 1887, Jan. 9, 1893, and Jan. 24, 1899)	Jan. 24, 1905
ANDREW D. WHITE, of New York (appointed Feb. 15, 1888, Mar. 19, 1894, and June 2, 1900)	June 2, 1906
RICHARD OLNEY, of Massachusetts (appointed Jan. 24, 1900)	Jan. 24, 1906
GEORGE GRAY, of Delaware (appointed Jan. 14, 1901)	Jan. 14, 1907
Citizens of Washington City:	
JOHN B. HENDERSON (appointed Jan. 26, 1892, Jan. 24, 1898, and Jan. 27, 1904)	Jan. 27, 1910
ALEXANDER GRAHAM BELL (appointed Jan. 24, 1898, and Jan. 27, 1904)	Jan. 27, 1910

Executive Committee of the Board of Regents.

JOHN B. HENDERSON, *Chairman.* ALEXANDER GRAHAM BELL.
ROBERT R. HITT.

PROCEEDINGS OF THE BOARD OF REGENTS FOR THE YEAR ENDING JUNE 30, 1904.

At a meeting held March 12, 1903, the Board of Regents adopted the following resolution:

Resolved, That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

In accordance with the above resolution, the Board met at 10 o'clock a. m. on December 8, 1903, and on January 27 and March 7, 1904.

REGULAR MEETING OF DECEMBER 8, 1903.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; Senator S. M. Cullom; Senator O. H. Platt; Senator F. M. Cockrell; Senator W. P. Frye, President pro tempore of the Senate; Representative Robert Adams, jr.; Representative Hugh A. Dinsmore; the Hon. Richard Olney; the Hon. John B. Henderson; the Hon. George Gray; Dr. A. Graham Bell, and the Secretary, S. P. Langley.

EXCUSES FOR NONATTENDANCE.

The Secretary read letters from Dr. J. B. Angell and the Hon. R. R. Hitt, explaining that important engagements prevented their attendance. He stated also that Dr. Andrew D. White was at present in Europe.

MINUTES OF PREVIOUS MEETINGS.

The Secretary read in abstract the minutes of the meetings of January 28 and March 12, and, there being no objection, they were approved.

NEW BUILDING FOR NATIONAL MUSEUM.

The Secretary read a report which showed that with the advice and consent of the Chancellor and the chairman of the executive committee, as required by the resolution of the Board of Regents adopted March 12, a contract had been made, under date of May 18, 1903, with Messrs. Hornblower & Marshall, architects, of Washington, D. C., for the necessary architectural services.

SPECIAL REPORT OF THE EXECUTIVE COMMITTEE.

In the absence of the chairman of the executive committee Doctor Bell made a verbal report of the action of the committee, in which he included certain resolutions on which he asked the approval of the Board.

REPORT OF SPECIAL COMMITTEE.

The Chancellor then read at length the report of the special committee appointed for the purpose of considering the question of defining the powers of the executive committee, and after a discussion, participated in by Senator Platt, Doctor Bell, Senator Henderson, and Judge Gray, Senator Henderson asked that the report might lie over until the January meeting.

The Chancellor suggested that it would be well to have the report and the exhibit of the past acts of the executive committee printed and communicated to the members of the Board.

The following resolutions were then adopted:

Resolved, That the report of the special committee, together with its exhibit, be printed and distributed to the members of the Board of Regents, and called up at the January meeting for action.

Resolved, That the executive committee's report, as presented by Doctor Bell, be printed and distributed to the members of the Board of Regents, and called up at the January meeting for action.

COMPILATION OF LAWS AFFECTING SMITHSONIAN INSTITUTION.

The Secretary presented the compilation of laws which had been prepared in accordance with a resolution offered by Senator Cockrell at the meeting of March 12, and adopted by the Board.

On motion, the manuscript was referred to Senator Cockrell for examination and decision as to printing.

REMOVAL OF SMITHSON'S REMAINS.

The Secretary read a letter from the Hon. William Henry Bishop, United States consul at Genoa, showing the need of action in the removal of James Smithson's remains, owing to the imminence of the proposed demolition of the cemetery in which they reposed.

Doctor Bell renewed the proposition which he made at the last meeting that the remains of Smithson be brought to this country at his expense.

After further remarks Judge Gray offered the following resolutions, which were adopted:

Resolved, That Dr. A. Graham Bell be appointed as a committee to take charge of the matter of the removal of the remains of James Smithson from Genoa to Washington, with the request that the negotiations and removal be conducted quietly and privately.

Resolved, That upon the conclusion of this duty, all expenses involved by it be reimbursed to Doctor Bell from the funds of the Institution.

The Board then adjourned.

ANNUAL MEETING OF JANUARY 27, 1904.

Present: Mr. Chief Justice Fuller (Chancellor), in the chair; the Hon. S. M. Cullom; the Hon. O. H. Platt; the Hon. F. M. Cockrell; the Hon. R. R. Hitt; the Hon. Robert Adams, jr.; the Hon. Hugh A. Dinsmore; Dr. J. B. Angell; the Hon. John B. Henderson; Dr. A. Graham Bell; the Hon. Richard Olney, and the Secretary, Mr. S. P. Langley.

EXCUSES FOR NONATTENDANCE.

Excuses for nonattendance were received from Senator Frye and Judge Gray, on account of important engagements, and from Dr. Andrew D. White, who was unable to attend owing to absence abroad.

MINUTES OF PREVIOUS MEETING.

The Secretary read in abstract the minutes of the previous meeting, and there being no objection they were declared approved.

REAPPOINTMENT OF REGENTS.

The Secretary announced that on January 12 the Speaker of the House had reappointed Representatives Hitt, Adams, and Dinsmore as Regents for two years; and also that Senator Henderson and Dr. A. Graham Bell had been reappointed for a term of six years by joint resolution approved by the President January 27, 1904.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Mr. Hitt, on behalf of the executive committee, presented the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1905, be appropriated for the service of the Institution, to be expended by the Secretary, with the advice of the executive committee, with full discretion on the part of the Secretary as to items.

ANNUAL REPORT OF THE SECRETARY.

The Secretary presented his report of the operations of the Institution for the year ending June 30, 1903, which was accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Senator Henderson, chairman, presented the report of the committee for the year ending June 30, 1903, which was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Senator Henderson, chairman, reported upon the present status of the proposed bequests of Addison T. Reid and Joseph White Sprague; also concerning the will of Wallace C. Andrews and the condition of the Hodgkins and Avery funds. He further stated that the Secretary had expended, under the authority of the Board, the sum of $14,225.02 on his experiments in mechanical flight, from January 1 to December 31, 1903.

The Secretary then submitted a statement on the work of the Institution, conducted since the date of his annual report (June 30, 1903), together with his plans for future operations.

REPORT OF THE SPECIAL COMMITTEE.

The Chancellor stated that the next matter to be disposed of was the report of the special committee to consider the question of defining the duties of the executive committee, and in this connection also the special report of the executive committee, but suggested that owing to lack of time it might be well to defer this until the meeting of March 7 next, which the Board approved.

REMOVAL OF SMITHSON'S REMAINS.

Doctor Bell's report upon the matter of the removal of Smithson's remains from Genoa to Washington, and their delivery to the charge of the Board, was next in order, but the hour having arrived at which it was necessary for a majority of the Regents to leave for their duties at the Capitol, the Board took a recess until 8 o'clock this evening, when the report would be received and considered.

8 O'CLOCK P. M.

The Board resumed its meeting at the Institution.

Present: The Hon. S. M. Cullom, the Hon. O. H. Platt, the Hon. F. M. Cockrell, the Hon. R. R. Hitt, the Hon. Robert Adams, jr., the Hon. Hugh A. Dinsmore, the Hon. John B. Henderson, the Hon. Richard Olney, Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

Senator Cullom was invited to preside.

Doctor Bell then read his report in full, and after discussion in which certain changes were suggested, it was accepted. (The report will be found appended hereto, p. xx.)

Mr. Adams then offered the following resolution, which was adopted:

Resolved, That the Board of Regents desire to record in the minutes of the Institution their profound appreciation of the voluntary service of Dr. Alexander Graham Bell in personally going to Genoa and returning with the remains

of James Smithson, that they might find a resting place in the grounds of the Institution he so nobly founded "for the increase and diffusion of knowledge among men."

Some further discussion took place with regard to the final disposition of the remains, and Senator Platt offered the following resolution, which was adopted:

Resolved, That the Chancellor and the Secretary, with the members of the executive committee, be appointed a committee upon the question of the final disposition of the remains of James Smithson, and of the monument to be erected to him, with power to act in the entire matter.

The Board then adjourned.

REGULAR MEETING OF MARCH 7, 1904.

Present: Mr. Chief Justice Fuller (Chancellor), in the chair; the Hon. William P. Frye, the Hon. S. M. Cullom, the Hon. O. H. Platt, the Hon. F. M. Cockrell, the Hon. R. R. Hitt, the Hon. Robert Adams, jr., the Hon. John B. Henderson, Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

EXCUSES FOR NONATTENDANCE.

The Secretary presented excuses in writing for nonattendance from Judge Gray, Doctor Angell, and Mr. Olney, on account of engagements, and added that Mr. Dinsmore had sent a message that he was compelled to leave the city and would not be present. Doctor White was still absent in Europe.

MINUTES OF PREVIOUS MEETING.

The minutes of the previous meeting were read in abstract, and there being no objection, were declared approved.

REPORT OF SPECIAL COMMITTEE.

The Chancellor, as chairman, read the report of the special committee appointed to consider the question of defining the powers of the executive committee.

The report was very fully discussed, and, on motion, was adopted.

SPECIAL REPORT OF EXECUTIVE COMMITTEE.

Mr. Bell read the report of the executive committee as presented by him at the meeting of December 8, 1903.

After discussion it was moved and carried that the consideration of the resolutions recommended by Doctor Bell be indefinitely postponed.

REPORT OF SPECIAL COMMITTEE ON THE DISPOSITION OF THE REMAINS OF JAMES SMITHSON.

The Chancellor stated that at the meeting of the Board of Regents held January 27, 1904, the following resolution was adopted:

Resolved, That the Chancellor and the Secretary, with the members of the executive committee, be appointed a committee upon the question of the final disposition of the remains of James Smithson and of the monument to be erected to him, with power to act in the entire matter.

The committee provided by the above resolution met on March 4, 1904, and after discussion adopted the following resolution:

Resolved, That a fitting tomb should be erected on the grounds of the Smithsonian Institution as a final resting place for the body of James Smithson, and that after consideration of the character and cost of such tomb Congress be requested to make an adequate appropriation for it.

NATIONAL GALLERY OF ART.

The Secretary then brought before the Board the matter of the will of the late Mrs. Harriet Lane Johnston, who left a number of paintings to the Corcoran Gallery of Art until a national gallery of art had been established by the Government. The Corcoran gallery had declined the pictures under these conditions, and Mr. Corcoran Thom had communicated with the Secretary with regard to the probability of the Government establishing such a national gallery of art under the Institution. After discussion, on motion of Senator Cullom, the matter was referred to the executive committee.

The Board then adjourned.

APPENDIX TO PROCEEDINGS OF REGENTS.

REPORT OF COMMITTEE ON THE TRANSFER OF THE REMAINS OF JAMES SMITHSON TO THE UNITED STATES.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: As the committee charged with the duty of bringing to the United States the mortal remains of James Smithson, the founder of the Smithsonian Institution, I beg to report the successful accomplishment of my mission; and the remains were handed over to the Smithsonian Institution last Monday, the 25th of January, 1904.

I reached Genoa, Italy, on the 25th of December, 1903, and next day presented my credentials to the American consul, Mr. William Henry Bishop, and to Mr. Noel Lees, for the committee of the British Burial Ground Fund Association.

On the 29th of December I made formal application for the remains of James Smithson, and on the 31st of December they were delivered into my custody. In accordance with the expressed wish

of the Regents, the exhumation was effected quietly and privately, only the American consul and six other witnesses being present in addition to the workmen employed.

I have the honor of submitting the following certificate from the American consul describing the exhumation:

THE CONSULATE OF THE UNITED STATES OF AMERICA,
Genoa, Italy.

To whom it may concern:

I, William Henry Bishop, consul of the United States of America, do hereby certify that on Thursday, December 31, 1903, at about 11 o'clock in the morning, I was present at the opening of the grave known without doubt or question to be that of James Smithson, in the old English cemetery of San Benigno at Genoa, said James Smithson having died at Genoa in the year 1829, and having been buried till now in the said cemetery. That on the opening of the grave the remains, consisting of little more than the skeleton, were seen clearly exposed to view, since no earth had been thrown upon the body, and the wooden coffin that contained it had entirely fallen to decay; that said remains were reverently removed from the grave and placed in a metal casket prepared to receive them; that the said metal casket was thereupon sealed up securely and put in the mortuary chapel of the cemetery, as in the custody of Dr. Alexander Graham Bell, to await his convenience in conveying it to America.

I further certify that there were present with me, and witnesses of all the circumstances of the above-described exhumation, the following persons: Dr. Alexander Graham Bell, Washington, D. C., especially commissioned by the Smithsonian Institution to convey the remains of James Smithson to the United States; Mrs. Alexander Graham Bell, his wife, Washington, D. C.; Noel Lees, esq., Genoa, Italy, official representative of the British Burial Ground Fund Association, in which the proprietorship of the said cemetery of San Benigno is vested; Gino Coppede, Genoa, architect and engineer, charged with the work of opening the tomb and grave of the said James Smithson, and of removing all the belongings of the said cemetery to the new site to which it is to be transferred; Giovanni Battista Firpo, Genoa, gardener by profession and paid custodian for many years past of the said cemetery and of the grave of James Smithson, having succeeded his father in the same office; Federico Guarini, the municipal guard deputed by the bureau of hygiene to be present on the occasion; Paolo Parodi, metal worker and chief undertaker, in transferring the remains to the casket and soldering up the same.

That the above-mentioned persons are all personally known to me, and known to fill the various functions respectively assigned to them above. That they have consented to be sworn as to the matters herein alleged, and that each has appended his signature hereunto as making oath to the truth of the statements, so far as each one individually is concerned, above set forth.

ALEXANDER GRAHAM BELL.
MABEL G. BELL.
NOEL LEES.
ARCHO GINO COPPEDE.
G. B. FIRPO.
FEDERICO GUARINI.
PAOLO PARODI.

In testimony whereof I have hereunto set my hand and affixed my seal of office this 31st day of December, 1903.

[SEAL.] WILLIAM HENRY BISHOP,
Consul of the United States of America at Genoa, Italy.

The above certificate of the American consul was signed by the witnesses named in the mortuary chapel of the cemetery after the casket had been soldered up in their presence. The witnesses named and the workmen employed then stood around with uncovered heads while the consul of the United States placed over the remains of James Smithson the American flag.

The casket was left in the mortuary chapel to await my convenience in transporting it to America; and Giovanni Battista Firpo, the gardener employed by the Smithsonian Institution as the custodian of the grave of James Smithson, was left in charge—he agreeing to remain in the mortuary chapel night and day until the removal of the remains.

On Saturday, the 2d of January, 1904, the foregoing witnesses again assembled in the mortuary chapel of the cemetery, and in their presence the metallic casket was placed within a coffin of strong wood.

Before the lid of the coffin was screwed down our consul, Mr. Bishop, placed upon the casket the seal of the consulate of the United States and covered the casket with an American flag. Mrs. Bell then placed within the coffin a wreath of leaves from the grave of Smithson, and all the witnesses contributed flowers.

Immediately before the removal of the remains from the mortuary chapel the following addresses were made:

REMARKS OF WILLIAM HENRY BISHOP, UNITED STATES CONSUL.

[On the occasion of the removal of the remains of James Smithson from the mortuary chapel of the cemetery of San Benigno, January 2, 1904.]

Dr. Alexander Graham Bell: You arrived here, my dear Dr. Graham Bell, charged by the Smithsonian Institution with the mission of removing to Washington the remains of the founder of that Institution, James Smithson, who has been buried till now in the cemetery where we stand, since his death at Genoa in the year 1829. Having been invited by you and by the Smithsonian Institution to aid you to what extent I might be able in this object, it has been a matter of great pride and pleasure to me that I have been allowed to do so.

All the steps necessary to such removal have now been taken. We have received the authorization of the governmental heads of the province, the city, and the British Burial Ground Fund, in which latter the title to the cemetery and the custody of the grave of James Smithson is vested, and all of these have kindly cooperated with us in the work.

The body of James Smithson has now been reverently raised from the earth; it has been placed in a case securely sealed, and this case stands ready to pass into the charge of the steamship company which will convey it to New York.

I assure you that it is with a feeling of real emotion that I have just now cast the American flag over the body of this illustrious man, this noble but as yet little known benefactor, as it is on the verge of beginning its journey to the United States. The flag adopts him already, as it were, in the substance, for our country, to which he has so long belonged in the spirit. He is now about to receive there a portion of the outward veneration and homage he so supremely merits, and which, owing to the modest circumstances of his life, and his interment here in some sense almost forgotten, he has never had.

Shall I admit that on taking possession of my post as consul at Genoa, I did not even know who James Smithson was? I may say that I was surprised to learn that he was buried at Genoa; more surprised still that he was an Englishman, who had never even set foot in America. He left his great bequest to the United States, then in its infancy, through admiring confidence in our future. It is likely that many, or even most, Americans are in the same condition as was I myself; for occasion has rarely arisen for taking thought as to the personality of the man. Happily this unenlightened condition of mind is about to cease.

Dr. Graham Bell, I wish you a hearty godspeed across the ocean with your precious freight. The American people will receive it with general gratification, and, through the Smithsonian Institution, will soon delight to pay it great honor.

REMARKS OF ALEXANDER GRAHAM BELL IN RESPONSE TO THE ABOVE.

Mr. Consul: It is with feelings of deep emotion that I undertake the transportation of the remains of James Smithson from the cemetery where they have so long reposed to their last resting place in the United States.

On behalf of the Smithsonian Institution allow me to thank you, Mr. Consul, for the unwearied zeal and care with which you have given me your assistance. Without your active cooperation and without your personal sympathy it would have been difficult indeed for me to have accomplished the object of my mission here.

On behalf of the Smithsonian Institution, I beg to thank you, too, Mr. Noel Lees, for your courtesy and attention; and trust that you will convey to His British Majesty's consul-general and to the committee of the British Church Burial Ground Fund my thanks and the thanks of the Institution I represent for their ready assistance in furthering my mission.

The United States of America will provide in Washington, D. C., a suitable and permanent resting place for the remains of her great benefactor, James Smithson, through the instrumentality of the Smithsonian Institution—the establishment created by the Government to perpetuate his name.

REMARKS OF NOEL LEES, ESQ.

[On behalf of the British Burial Ground Fund Committee.]

Dr. Graham Bell: I beg to thank you heartily for the words you have said with regard to the aid you have received from the burial board and myself. Although we regret to lose the remains of James Smithson, we at the same time feel that in the country to which he left his money, with such charitable intent, his remains will receive the honor and glory which have so long been due to them, and we must understand that our loss is America's gain. To us it will always remain a pleasant memory that, from the date of his burial to the present day, we have had in our custody in this picturesque little churchyard the remains of a man whose foresight and kindness have enabled so many in the New World to benefit.

Upon the conclusion of these remarks the remains of James Smithson were transported to the North German Lloyd steamship *Princess Irene*, accompanied by the American consul and myself. The steamer left Genoa for New York on the 7th of January, 1904, touching at Naples and Gibraltar on the way. The American consul at Naples, General Byington, contributed an American flag to cover the wooden coffin containing the remains.

Not knowing the nature of the reception arrangements that were being made in the United States, I telegraphed from Gibraltar to my son-in-law, Mr. Gilbert H. Grosvenor, expressing the hope that the remains of James Smithson would be received with as much honor as those of John Howard Payne.

After conferring with the Secretary of the Smithsonian Institution, Mr. Grosvenor laid the substance of my telegram before the President of the United States, who immediately responded by requesting the Secretary of the Navy to detail the U. S. dispatch-boat *Dolphin* to meet the *Princess Irene* on her arrival at quarantine, escort her to the pier at Hoboken, N. J., and then bring the remains to Washington.

At the request of Mr. Grosvenor a squadron of United States cavalry was also detailed to escort the remains from the navy-yard to their resting place here. Mr. Grosvenor has made a report to me of the correspondence which resulted in this cooperation of the United States Government, which will be found in the appendix.

As your committee charged with the duty of bringing the remains to the Smithsonian Institution, I have expressed to the President and to the Secretary of the Navy and to the Secretary of War my sincere appreciation of these acts of courtesy, which have given a national character to the reception accorded to the remains of James Smithson on their arrival in the United States.

On Monday, the 25th of January, 1904, I handed over, at the Smithsonian Institution, to Senator Frye, as the representative of the Board of Regents, the remains of this great benefactor of the United States.

I have the honor to present as an appendix to this report the following documents:

A. Copy of the application of your committee to the committee of the British Burial Ground Fund Association for the custody of the remains of James Smithson, with the reply.

B. Copy of the application of your committee to the prefect of the province of Genoa for permission to remove the remains of James Smithson to the United States, with a copy of the decree permitting such removal.

C. Copy of a certificate made by the British consul-general at Genoa, at the request of the municipal bureau of hygiene, stating that no objection existed on the part of the British consulate-general to the removal of the remains of James Smithson.

D. Certificate of the acting mayor of Genoa that all the requirements of the existing regulations on mortuary matters had been complied with.

E. Copy of the final certificate of the American consul, given to your committee on board the steamer *Princess Irene* as she was about to leave Genoa for New York.

F. Copy of letter from Lieut. Commander J. H. Gibbons, U. S. Navy, delivered on board the steamer *Princess Irene* upon her arrival at quanantine, notifying your committee of the action of the Navy Department in detailing the

U. S. S. *Dolphin* to convey the remains of James Smithson from New York to Washington.

G. Copy of the remarks of your committee at the Smithsonian Institution January 25, 1904, in handing over the remains of James Smithson to Senator Frye as the representative of the Board of Regents, together with the reply of Senator Frye.

H. Copy of report of Mr. Gilbert H. Grosvenor, M. A., concerning the correspondence which resulted in the cooperation of the United States Government in transporting the remains of James Smithson from New York to the Smithsonian Institution in Washington, D. C.

I. Copy of telegrams and letters sent by your committee to the President of the United States, and to the Secretary of the Navy, and to the Secretary of War, in acknowledgment of Government courtesies.

J. Statement of expenses incurred in the removal of the remains of James Smithson to the United States.

I may say that it is entirely due to the ability and energy of our consul at Genoa that the transfer of the remains to the United States was effected at all. Without his earnest and intelligent assistance it would have been difficult indeed, if not impossible, for me to have accomplished the object of my mission abroad. No less than five distinct permits had to be obtained from different government officials in Italy, besides a certificate from the British consul-general and permission from the British Burial Ground Fund Association. In addition to the official permits required special difficulties were encountered which at first sight seemed insurmountable, but which were successfully overcome by the tact and ability of our consul at Genoa.

Respectfully submitted.

ALEXANDER GRAHAM BELL,
Committee on the Transfer of the Remains of James Smithson to the United States.

WASHINGTON, D. C., *January 27, 1904.*

APPENDIX A.—*Application to the committee of the British Burial Ground Fund Association for the custody of the remains of James Smithson, with the reply.*

EDEN PALACE HOTEL,
Genoa, December 29, 1903.

DEAR SIR: I have the honor to request that the remains of James Smithson, now resting in the old cemetery on the heights of San Benigno, be delivered to me for transportation to the United States.

By the will of James Smithson the United States of America became his heir. The Government of the United States accepted the bequest; and, in conformity with the terms of the will created in Washington, D. C., an establishment for the increase and diffusion of knowledge among men under the title of "The Smithsonian Institution."

It appears that an immediate necessity exists for the removal of the remains of this great benefactor of the United States from the cemetery where they have so long reposed; and it seems peculiarly appropriate that the body of Smithson

should now be taken to America and cared for permanently by the institution which bears his name.

As the authorized representative of the Smithsonian Institution for this purpose, I respectfully make application for the custody of the remains.

I am, sir, yours, respectfully,

ALEXANDER GRAHAM BELL,
Regent of the Smithsonian Institution.

NOEL LEES, Esq.,
Care of His Britannic Majesty's Consul-General, for the Committee, British Burial Ground Fund, Genoa, Italy.

REPLY TO THE ABOVE.

CARE OF HIS BRITANNIC MAJESTY'S CONSUL-GENERAL,
Genoa, January 2, 1904.

DEAR SIR: Your favor of December 29, 1903, to hand. On the 31st of the same month the remains of James Smithson, buried in the British cemetery at San Benigno in this city, were exhumed in the presence of the United States consul, yourself (representing the Smithsonian Institute), myself, and other witnesses. The remains were then formally handed over to you, and I now confirm the same in this letter, understanding that the remains will be transported to the United States.

I remain, dear sir, yours, faithfully,

NOEL LEES,
Assistant Secretary British Burial Ground Fund, Genoa.

Dr. A. GRAHAM BELL,
Eden Palace Hotel, Genoa.

APPENDIX B.—*Application to the prefect of the province of Genoa for permission to remove the remains of James Smithson to the United States, with a copy of the decree permitting such removal.*

[Translation.]

GENOA, *December 29, 1903.*

The undersigned has the honor to request your excellency to grant him permission to remove from Genoa to Washington, United States of America, the remains of James Smithson, buried in the English Protestant Cemetery of San Benigno, at Genoa.

With great respect and esteem, the commissioner charged with the same,

ALEXANDER GRAHAM BELL.

UNITED STATES CONSULATE AT GENOA, ITALY,
Genoa, December 29, 1903.

I, the undersigned, consul of the United States of America at Genoa, hereby certify that Dr. Alexander Graham Bell is the person duly authorized by the Smithsonian Institution, of Washington, to take charge of the remains of James Smithson for the purpose of transporting the same to America.

[SEAL.] WILLIAM HENRY BISHOP,
Consul of the United States of America.

REPLY TO THE ABOVE.

[Form for authentication of signature.]

CONSULAR SERVICE, UNITED STATES OF AMERICA,
December 29, 1903.

I, William Henry Bishop, consul of the United States at Genoa, Italy, do hereby certify that the signature of the Marchese Garroni, prefect of the province of Genoa, at the foot of the paper hereto annexed, is his true and genuine signature, made and acknowledged in my presence, and that the said Marchese Garroni is personally known to me.

In witness whereof I have hereunto set my hand and affixed the seal of the

consulate at Genoa, Italy, the day and year next above written, and of the Independence of the United States the one hundred and twenty-eighth.

[SEAL.] WILLIAM HENRY BISHOP,
Consul of the United States.

[Translation of the prefect's decree.]

ROYAL PREFECTURE OF GENOA.

The prefect of the province, upon the demand of Mr. Alexander Graham Bell, bearing in mind the certificate of illness and the extract from the certificate of death relevant, as also the receipt No. 786/10641 delivered by the fiscal register of Genoa, on this date, for the required payment of the tax for a governmental permit to the amount of 360 lire.

Bearing in mind the law concerning the care of hygiene and the public health of December 22, 1888, No. 5849, series 3, and the regulation of mortuary affairs of July 25, 1892;

Decrees that there is authorized, subject to the observance of the existing sanitary requirements, the transportation of the remains of James Smithson, deceased of a malady not contagious, from Genoa to Washington (United States of America).

Genoa, December 29, 1903.

The prefect, N. GARRONI.

APPENDIX C.—*Copy of a certificate made by the British consul-general at Genoa, at the request of the municipal bureau of hygiene, stating that no objection existed on the part of the British consulate-general to the removal of the remains of James Smithson.*

[Translation.]

CONSULATE-GENERAL OF GREAT BRITAIN,
Genoa, December 30, 1903.

There is not known on the part of this royal consulate-general any reason why the representatives of the late Mr. Smithson, deceased in the year 1829, should not remove his body from the cemetery of San Benigno, which has been expropriated.

[SEAL.] WILLIAM KEENE, *Consul-General.*

APPENDIX D.—*Certificate of the acting mayor of Genoa that all the requirements of the existing regulations on mortuary matters had been complied with.*

[Form for authentication of signature.]

CONSULAR SERVICE, UNITED STATES OF AMERICA,
Genoa, Italy, January 5, 1904.

I, William Henry Bishop, consul of the United States at Genoa, Italy, do hereby certify that the signature of Bernabo Brea, acting mayor at Genoa, Italy, at the foot of the paper hereto annexed, is his true and genuine signature, made and acknowledge in my presence, and that the said Bernabo Brea is personally known to me.

In witness whereof I have hereunto set my hand and affixed the seal of the consulate at Genoa, Italy, the day and year next above written, and of the Independence of the United States the one hundred and twenty-eighth.

[SEAL.] WILLIAM HENRY BISHOP,
Consul of the United States.

[Translation of the mayor's certificate.]

CITY HALL OF GENOA, OFFICE OF HYGIENE.

The mayor certifies that the body of James Smithson has been inclosed in two coffins, the one of zinc and the other of strong wood, and that there have been observed throughout all the requirements of the existing regulations on mortuary matters, articles 31, 32, 33.

Genoa, January 4, 1904.

For the mayor:

BERNABO BREA, *The Assistant.*

APPENDIX E.—*Final certificate of the American consul given on board the steamer Princess Irene as she was about to sail for New York.*

CONSULAR SERVICE, UNITED STATES OF AMERICA,
Genoa, Italy.

I, William Henry Bishop, United States consul at Genoa, Italy, hereby certify that on December 31, 1903, in my presence and in that of Dr. Alexander Graham Bell and six other credible witnesses whose names are of record, the mortal remains of James Smithson were exhumed from the English cemetery on the heights of San Benigno, at Genoa, where they had reposed since his burial in the year 1829, and that they were placed, securely sealed, and under guard in the mortuary chapel of the said cemetery; and that, on January 2, 1904, they were delivered, accompanied by Dr. Graham Bell and myself, on board the steamer *Princess Irene*, of the North German Lloyd Steamship Company, to be conveyed to Washington, D. C., United States of America, by Dr. Alexander Graham Bell, who had been especially commissioned by the Smithsonian Institution, of Washington, to come to Genoa for that purpose.

Given on board the steamer *Princess Irene*, about to sail for New York, this 7th day of January, 1904.

[SEAL.] WILLIAM HENRY BISHOP,
United States Consul at Genoa, Italy.

APPENDIX F.—*Letter from Lieut. Commander J. H. Gibbons, U. S. Navy, in command of the U. S. S. Dolphin, delivered on board the steamer Princess Irene, notifying your committee of the action of the Navy Department in detailing the U. S. S. Dolphin to convey the remains of James Smithson from New York to Washington.*

U. S. S. DOLPHIN,
New York, N. Y., January 20, 1904.

SIR: 1. I have the honor to inform you that the Navy Department has ordered the *Dolphin* to escort the *Princess Irene* to her pier at Hoboken, after which she is to receive the remains of the late James Smithson.

2. The commandant of the navy-yard, New York, will send a tug alongside the *Princess Irene* after she arrives at her pier, and has made the necessary arrangements with the health and custom authorities so that there will be no delay in transferring the remains to the *Dolphin*.

3. The *Dolphin* will anchor off the Battery and remain there until early daylight of the next day after the remains have been received on board, when she will sail for Washington, D. C. In case you wish to accompany the remains to Washington I am authorized to offer you a passage on the *Dolphin*. It was the intention of the Secretary of the Smithsonian Institution, Professor Langley, to write to you in regard to this matter, so that you would receive the letter off quarantine.

4. In case there are to be any passengers for the trip to Washington it is requested that they be on board by midnight of the day on which the steamer arrives. This ship can be communicated with by telegraph or telephone by addressing the dock department office, pier 1, North River, at the Battery, where there is a comfortable boat landing. A steam launch will be at this landing at intervals during the day and night, the last trip leaving the ship at 11.30 p. m.

Very respectfully,
J. H. GIBBONS,
Lieutenant-Commander, U. S. Navy, Commanding.

Prof. A. GRAHAM BELL,
Steamship Princess Irene.

APPENDIX G.—*Remarks of Alexander Graham Bell at the Smithsonian Institution January 25, 1904, in handing over the remains of James Smithson to Senator Frye as the representative of the Board of Regents, together with the reply of Senator Frye.*

REMARKS OF A. G. BELL.

MR. SENATOR: I have the honor of handing over to the Smithsonian Institution the mortal remains of its founder, James Smithson, fellow of the Royal Society of London, England, who died in Genoa, Italy, on the 26th of June, 1829.

For nearly seventy-five years the body of Smithson has lain in an almost forgotten grave in the picturesque little British cemetery on the heights of San Benigno, in Genoa. City improvements have now rendered necessary the expropriation of the cemetery and the removal of the remains; and at the last meeting of the Board of Regents of the Smithsonian Institution I was appointed a committee to arrange for the transfer of the body of Smithson to the United States.

Upon my arrival in Genoa I was afforded every possible facility for the accomplishment of my mission by the provincial and municipal authorities, by His British Majesty's consul-general (Mr. Keene), and by the committee of the British Burial Ground Fund Association, in which is vested the ownership of the cemetery, as well as by our own consul, Mr. William Henry Bishop, to whom I am indebted for invaluable assistance.

On the 31st of December, 1903, the tomb of Smithson was opened in my presence as the representative of the Smithsonian Institution, and in the presence of the American consul, Mr. Bishop, and six other witnesses. The remains of James Smithson were reverently raised from the grave and placed in a metallic casket, over which the consul of the United States cast the American flag, while the witnesses stood around with uncovered heads.

The casket was left in the mortuary chapel of the cemetery—securely sealed and under guard—until the 2d day of January, 1904, when it was placed in a coffin of strong wood, as required by Italian law, and was then removed to the North German Lloyd steamship *Princess Irene*, accompanied by the American consul and myself.

The steamer left Genoa on the 7th of January; and upon arrival in the United States the remains of James Smithson were received with national honors by direction of the President and of the Secretary of the Navy and the Secretary of War.

The remains were transported to Washington on the U. S. dispatch boat *Dolphin*, and have been escorted to the Smithsonian Institution by United States cavalry.

And now, Mr. Senator, my mission is ended, and I deliver into your hands, as the representative of the Board of Regents of the Smithsonian Institution, the remains of this great benefactor of the United States.

REMARKS OF SENATOR FRYE.

SIR: The Smithsonian Institution receives with profound gratitude the remains of its distinguished founder. Providence, every now and then, seems to place in the world a man and inspires him with a purpose to elevate his fellow-men. Such a man was Mr. Smithson, the founder of this Institution. The spirit, sir, which prompted you to such earnest endeavor, resulting as it did in taking these remains from their resting place in a country foreign to him and foreign to us, and bringing them here, where for so many years we have enjoyed the rich fruits of his splendid benefaction, your countrymen will appreciate. His grave here will be an incentive to earnest, faithful, wise, and discreet endeavor to carry out his lofty purposes, and, sir, it will be to our people a sacred spot while the Republic endures.

APPENDIX II.—*Report of Mr. Gilbert H. Grosvenor, M. A., concerning the correspondence which resulted in the cooperation of the United States Government in transporting the remains of James Smithson from New York to the Smithsonian Institution in Washington, D. C.*

HUBBARD MEMORIAL HALL,
Washington, D. C., January 23, 1904.

DEAR MR. BELL: I beg to submit the following report on arrangements for the reception of James Smithson. On January 7 I received the following cablegram from you:

"GENOA, *January 7, 1904.*

"GILBERT GROSVENOR,
"*Memorial Building, Sixteenth and M, Washington, D. C.*

"We bring Smithson's remains steamship *Princess Irene*, touching Naples and Gibraltar. See Henderson, Hitt, Langley about formalities of landing and transfer to Washington.

"GRAHAM BELL."

I thereupon consulted with Mr. Langley who assured me that all formalities were being arranged so that the remains might be admitted into this country without delay. On Sunday, January 10, I cabled to you at Gibraltar as follows:

"BELL, *Princess Irene, Gibraltar.*

"Congratulations. Formalities arranged.

"GILBERT GROSVENOR."

On Monday, January 11, I received the following cablegram from you:

"GIBRALTAR, *January 11, 1904.*

"GILBERT GROSVENOR, *Washington, D. C.*

"Hope Smithson's remains will be received with as much honor as those of John Howard Payne. Notify me at quarantine what to expect.

"GRAHAM BELL."

Upon receipt of this message I called upon Dr. S. P. Langley and expressed your desire that suitable honors be rendered James Smithson upon the arrival of the remains in this country. I then addressed the following letter to the President of the United States, Hon. Theodore Roosevelt:

"HUBBARD MEMORIAL HALL,
"*Washington, D. C., January 11, 1904.*

"SIR: The remains of James Smithson, the founder of the Smithsonian Institution, are now being brought to the United States by Dr. Alexander Graham Bell, one of the Regents of the Institution. The remains left Gibraltar this morning on the steamer *Princess Irene*, and are due in New York about the 20th instant. Dr. Graham Bell has cabled me urging that the remains be received with as much honor as those of John Howard Payne. It would seem most appropriate that a Government vessel, a ship of war, a revenue cutter, or even a tug, be detailed to meet the *Princess Irene* when she enters the harbor of New York and receive Smithson's remains. This official tribute from the American nation seems due a man who bequeathed his entire fortune to a people whom he had never seen. As the time is urgent I take the liberty of addressing you directly, rather than through official channels. I would respectfully beg, in case your honor does not deem it fitting to order detailed a vessel to welcome Smithson in the harbor of New York, that I be so informed at once, in order that private plans for paying honor to this illustrious benefactor may then be carried out.

"I beg to remain, most respectfully,

"GILBERT H. GROSVENOR.

"Hon. THEODORE ROOSEVELT,
"*President of the United States.*"

On Tuesday, January 12, I received word from the Secretary of the Navy that my request for a war ship had been approved by the President, and I was asked to send a formal application for the detail of the *Dolphin*. I thereupon forwarded the following application:

"JANUARY 12, 1904.

"SIR: Pursuant to the request from the Secretary of the Navy, I beg herewith formally and respectfully to petition that the *Dolphin* be detailed to receive the remains of James Smithson, the founder of the Smithsonian Institution, in New York Harbor and convey them to Washington. I beg to remain,

"Most respectfully,

"GILBERT H. GROSVENOR.

"Hon. THEODORE ROOSEVELT,
"*President of the United States, Washington.*"

The *Dolphin* was thereupon detailed and ordered to New York.

On January 18 I called upon the Chief of Staff, Lieut. Gen. Adna R. Chaffee, and requested a military escort to receive the remains of James Smithson when they reached this city, and on January 19 forwarded the following formal application:

"JANUARY 18, 1904.

"SIR: The remains of James Smithson, the founder of the Smithsonian Institution, will reach Washington on Friday or Saturday of this week. The remains

are to be brought from New York on the *Dolphin*, which was especially detailed by the Secretary of the Navy to proceed to New York, receive them from the *Princess Irene*, when the latter ship arrived from Genoa, and bring them to Washington. When the *Dolphin* reaches this city the remains will be conveyed without ceremony to Oak Hill Cemetery, where they will be deposited until action is taken as to their final disposition. It would seem most appropriate that an escort of 50 or 100 cavalrymen be detailed to accompany the remains from the dock to the cemetery. I have the honor to respectfully request, therefore, that an escort be detailed for this purpose. For your information I beg to inclose a copy of the letter addressed to the President, which was approved by him and led to the detail of the *Dolphin*.

"Very respectfully,

"GILBERT H. GROSVENOR.

"Lieut. Gen. ADNA R. CHAFFEE, U. S. Army.

"*War Department, Washington, D. C.*"

On January 20 the following letter was received from General Chaffee, stating that the military escort had been detailed:

"JANUARY 19, 1904.

"SIR: I have just received your note of January 19, requesting an escort of cavalry for the remains of Mr. James Smithson, the founder of the Smithsonian Institution, which are to arrive, as you say, on Friday or Saturday of this week on the *Dolphin*. I have instructed the commanding officer of Fort Myer to hold in readiness an escort of 50 men, properly officered, and an artillery caisson to convey the remains. In order to give further direction in this matter to avoid delay and to insure promptness, it will be necessary for you to advise me of the time and place the escort should be directed to report to receive the remains. Will you please make certain that I am informed of this matter at least twelve hours in advance?

"Very respectfully, ADNA R. CHAFFEE,

"*Lieutenant-General, Chief of Staff.*

"Mr. GILBERT H. GROSVENOR,

"*Editor National Geographic Magazine,*

"*Hubbard Memorial Hall, Sixteenth and M streets,*

"*Washington, D. C.*"

For your information, I sent you January 19, care of the quarantine officer, the following telegram:

"Dr. ALEXANDER GRAHAM BELL,

"*Passenger on Board Steamship Princess Irene,*

"*Arriving New York January 20:*

Dolphin will meet *Irene*, fire salutes, and accompany to dock. The *Dolphin* will receive Smithson and carry to Washington. You can come by *Dolphin* or not. You are reelected Regent. Langley and Daisy meet you at dock. Elsie and I sorry we can not.

"GILBERT H. GROSVENOR."

And on January 20 a second message, as follows:

"Dr. ALEXANDER GRAHAM BELL,

"*Passenger on Board Steamship Princess Irene,*

"*Arriving New York January 20:*

"Have arranged military escort and caisson meet Smithson on arrival here.

"GILBERT H. GROSVENOR."

Letters to General Chaffee and Admiral Taylor follow:

"JANUARY 22, 1904.

"SIR: I beg to acknowledge with thanks your courteous favor of the 19th instant. Admiral Taylor, Chief of the Bureau of Navigation, informs me that he has already sent you word that James Smithson will leave the navy-yard Monday morning, January 25, at 10 o'clock. With much appreciation of your courtesy in this matter, I beg to remain,

"Very respectfully,

"GILBERT H. GROSVENOR.

"Lieut. Gen. ADNA R. CHAFFEE, U. S. Army,

"*War Department, Washington, D. C.*"

"JANUARY 22, 1904.

"SIR: I wish to thank you most cordially for your courtesy in the matter of the marine guard for James Smithson, the founder of the Smithsonian Institution.

"Yours, very respectfully,

"GILBERT H. GROSVENOR.

"Rear-Admiral H. C. TAYLOR, U. S. Navy,

"*Chief of Bureau of Navigation, Navy Department, Washington, D. C.*"

The following letters from Admiral Taylor give the details of the arrangements at the navy-yard:

"JANUARY 22, 1904.

"SIR: I have the honor to inform you that instructions have been sent to the commandant of the navy-yard, Washington, to arrange for the debarkation of the remains of the late James Smithson, esq., from the U. S. S. *Dolphin*, about 9.30 o'clock, Monday morning, the 25th instant, and for their escort, with ceremony, from alongside the ship to the navy-yard gate, where they will be transferred to the custody of an escort of army troops. A copy of the said instructions is inclosed.

"Very respectfully,

H. C. TAYLOR,

"*Acting Secretary.*

"The PRESIDENT, NATIONAL GEOGRAPHIC SOCIETY,

"*Washington, D. C.*"

"NAVY DEPARTMENT,

"*Washington, D. C., January 22, 1904.*

"SIR: You will please give the necessary instructions for the remains of the late James Smithson, esq., to be landed from the U. S. S. *Dolphin*, about 9.30 o'clock, Monday morning, the 25th instant, and escorted with ceremony to the navy-yard gate, where, punctually at 10 o'clock, the remains will be delivered to the escort of army troops which will be in waiting outside the gate.

"As large a force of marines as may be available will be paraded as an escort, the Commandant of the Marine Corps having been directed to send a detachment and the Marine Band to report to you for this purpose. The customary detail of naval enlisted men as body bearers will be made, these to accompany the remains until the transfer to the army escort has been effected.

"The Department desires as many officers of the station as may be spared from their duties to attend the ceremony. Uniform for officers of the Navy will be 'Dress,' with or without overcoats, at your discretion. The Smithsonian Institution and the National Geographical Society have been notified of these instructions, and you may expect their representatives to be in attendance from the beginning of the ceremony.

"When the army escort moves off with the remains, the part taken by the Navy in the ceremony will terminate.

"Very respectfully,

H. C. TAYLOR.

"*Acting Secretary.*

"The COMMANDANT OF THE NAVY-YARD,

"*Washington, D. C.*"

Very truly, yours,

GILBERT H. GROSVENOR.

DR. ALEXANDER GRAHAM BELL,

Board of Regents, Smithsonian Institution,

Committee on the transfer of the remains of

James Smithson to the United States.

APPENDIX I.—*Acknowledgment of Government courtesies made by your committee to the President of the United States and to the Secretary of the Navy and Secretary of War.*

NEW YORK, *January 21, 1904.*

MR. PRESIDENT: I have the honor to announce the safe arrival in the United States of the remains of James Smithson, founder of the Smithsonian Institution, by steamer *Princess Irene*, and to thank you for detailing the *Dolphin* to convey the remains to Washington.

GRAHAM BELL,

Regent in Charge of Remains.

The PRESIDENT OF THE UNITED STATES,

White House, Washington, D. C.

1331 CONNECTICUT AVENUE,
Washington, D. C., January 25, 1904.

MY DEAR SIR: At the last meeting of the Board of Regents of the Smithsonian Institution I was appointed a committee charged with the duty of bringing to the Institution the body of its distinguished founder, James Smithson.

As such committee allow me to express my deep indebtedness to you for the assistance rendered by the Navy of the United States in transporting the remains from New York to Washington and for the assistance rendered by the Army in completing the transportation to the Smithsonian Institution.

Yours, respectfully,

ALEXANDER GRAHAM BELL,
Regent of the Smithsonian Institution.

The PRESIDENT OF THE UNITED STATES,
White House.

1331 CONNECTICUT AVENUE,
Washington, D. C., January 25, 1904.

MY DEAR SIR: I beg to inclose for your information a copy of a note I have addressed to the President of the United States expressing my sincere appreciation of the assistance rendered by the Navy in transporting the remains of the founder of the Smithsonian Institution from New York to the navy-yard in Washington, D. C.

Yours, respectfully,

ALEXANDER GRAHAM BELL,
Regent of the Smithsonian Institution.

The SECRETARY OF THE NAVY,
Navy Department.

1331 CONNECTICUT AVENUE,
Washington, D. C., January 25, 1904.

MY DEAR SIR: I beg to inclose for your information a copy of a note I have addressed to the President of the United States expressing my sincere appreciation of the assistance rendered by the Army in transporting to the Smithsonian Institution the body of its founder, James Smithson.

Yours, respectfully,

ALEXANDER GRAHAM BELL,
Regent of the Smithsonian Institution.

The SECRETARY OF WAR,
War Department.

APPENDIX J.—*Statement of expenses incurred in the removal of the remains of James Smithson to the United States (supported by vouchers, which have been handed to the Secretary of the Smithsonian Institution).*

	Lire.
Exportation tax	360.00
Undertaker's bill	81.85
Mason's bill	17.00
Gardener's bill, with his assistants	69.00
Freight to New York from cemetery	430.00
Total	957.85

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1904.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the U. S. National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1904, and balances of former years:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1904.

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added, by authority of Congress, February 8, 1867, the residuary legacy of Smithson, savings from income and other sources, to the amount of $134,831.

To this also have been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500; the proceeds of the sale of Virginia bonds, $51,500; a gift from Thomas G. Hodgkins, of New York, of $200,000 and $8,000, being a portion of the residuary legacy of Thomas G. Hodgkins, and $1,000, the accumulated interest on the Hamilton bequest, savings from income, $25,000, making in all, as the permanent fund, $937,000.

The Institution also holds the additional sum of $42,000, received upon the death of Thomas G. Hodgkins, in registered West Shore Railroad 4 per cent bonds, which were, by order of this committee, under date of May 18, 1894, placed in the hands of the Secretary of the Institution, to be held by him subject to the conditions of said order.

Statement of receipts and expenditures from July 1, 1903, to June 30, 1904.

RECEIPTS.

Cash on hand July 1, 1903		$55,507.67	
Interest on fund July 1, 1903	$27,964.17		
Interest on fund January 1, 1904	28,110.00		
		56,074.17	
Interest to January 1, 1904, on West Shore bonds		1,680.00	
			$113,261.84
Cash from sales of publications		353.37	
Cash from repayments, freight, etc		10,328.02	
			10,681.39
Total receipts			123,943.23

EXPENDITURES.

Buildings:			
Repairs, care, and improvements	$4,128.73		
Furniture and fixtures	467.78		
		$4,596.51	
General expenses:			
Postage and telegraph	230.74		
Stationery	584.97		
Incidentals (fuel, gas, etc.)	3,727.45		
Library (books, periodicals, etc.)	4,250.81		
Salaries [a]	26,383.85		
Gallery of art	84.40		
Meetings	569.75		
		35,832.00	
Publications and researches:			
Smithsonian contributions	2,102.85		
Miscellaneous collections	4,940.74		
Reports	1,433.13		
Special publications	201.70		
Explorations	2,176.00		
Researches	3,486.71		
Apparatus	182.95		
Hodgkins fund	12,625.89		
Bell & Kidder fund	1,925.50		
		29,075.47	
Literary and scientific exchanges		7,790.92	
			77,294.90
Balance unexpended June 30, 1904			46,648.33

[a] In addition to the above $26,383.85, paid for salaries under general expenses, $10,790.18 were paid for services, viz: $3,928.94 charged to building account, $179.50 to furniture and fixtures account, $2,804.21 to researches account, $2,713.44 to library account, $164.13 to reports account, and $999.96 to Hodgkins fund account.

The cash received from the sale of publications, from repayments, freights, and other sources is to be credited to the items of expenditure as follows:

Smithsonian contributions	$44.77		
Miscellaneous collections	294.56		
Reports	14.04		
		$353.37	
Exchanges		9,718.33	
Incidentals		409.69	
Explorations		200.00	
			$10,681.39

The net expenditures of the Institution for the year ending June 30, 1904, were therefore $66,613.51, or $10,681.39 less than the gross expenditures, $77,294.90, as above stated.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1904, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1904.

RECEIPTS.

Appropriated by Congress for the fiscal year ending June 30, 1904, "for expenses of the system of international exchanges between the United States and foreign countries under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals" (sundry civil act, March 3, 1903)	$26,000.00

DISBURSEMENTS.

[From July 1, 1903, to June 30, 1904.]

Salaries or compensation:

1 acting curator, 12 months, at $225	$2,700.00
1 chief clerk, 12 months, at $183.33	2,199.96
1 clerk, 12 months, at $150	1,800.00
1 clerk, 12 months, at $125	1,500.00
1 clerk, 11 months, at $116.66	1,283.26
1 clerk, 12 months, at $80	960.00
1 clerk, 12 months, at $55	660.00
1 stenographer, 12 months, at $100	1,200.00

Salaries or compensation—Continued.			
1 packer, 11 months, at $55		$605.00	
1 workman, 11 months, at $60		660.00	
1 messenger, 9 months, at $40		360.00	
1 messenger, 12 months, at $30		360.00	
1 messenger, 12 months, at $25		300.00	
1 agent, 6 months, at $75		450.00	
1 agent, 6 months, at $15		90.00	
1 acting agent, 2 months, at $91.66⅔		183.33	
Total salaries or compensation		15,311.55	
General expenses:			
Books	$81.11		
Boxes	1,222.00		
Freight	5,648.97		
Postage	404.00		
Supplies	108.91		
Stationery	548.51		
		8,013.50	
Total disbursements			$23,325.05
Balance July 1, 1904			2,674.95

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1903.

Balance July 1, 1903, as per last report			$1,822.14
Salaries or compensation:			
1 agent, 6 months, at $15	$90.00		
Total salaries or compensation		$90.00	
General expenses:			
Boxes	335.44		
Freight	1,294.22		
Stationery	72.28		
Supplies	.76		
		1,702.70	
Total disbursements			1,792.70
Balance July 1, 1904			29.44

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1903, as per last report	$0.88

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the

purchase of necessary books and periodicals, $40,000, of which sum not exceeding $1,500 may be used for rent of building" (sundry civil act, March 3, 1903) — $40,000.00

DISBURSEMENTS.

Salaries or compensation:

1 chief of bureau, 4 months, at $375; 8 months, at $333.33	$4,166.64
1 ethnologist in charge, 1 month, at $333.33	333.33
1 ethnologist, 9 months, at $200	1,800.00
1 ethnologist, 3 months, at $166.67; 8 months, at $200	2,100.01
1 ethnologist, 4 months, at $166.67; 8 months, at $125	1,666.68
1 ethnologist, 12 months, at $133.33	1,599.96
1 ethnologist, 8 months, at $125	1,000.00
1 ethnologist, 12 months, at $125	1,500.00
1 assistant ethnologist, 4 months, at $75; 4 months, at $100	700.00
1 ethnologic assistant, 3 months, at $100	300.00
1 assistant, 6 months, at $125	750.00
1 illustrator, 12 months, at $166.67	2,000.04
1 editor, 12 months, at $100	1,200.00
1 assistant editor, 6 months 2 days, at $100	606.45
1 assistant editor, 65 days, at $3	195.00
1 clerk, 3 months, at $125	375.00
1 clerk, 12 months, at $100	1,200.00
1 clerk, 3 months 9 days, at $100; 8 months, at $90	1,049.35
1 clerk, 12 months, at $100	1,200.00
1 clerk, 12 months, at $75	900.00
1 stenographer and typewriter, 34 days, at $60	67.44
1 stenographer and typewriter, 2½ months 14 days, at $50	147.96
1 stenographer, 1½ months 14 days, at $50	98.33
1 typewriter, 5½ months 16 days, at $50	301.14
1 skilled laborer, 12 months, at $60	720.00
1 messenger, 7 months 3 days, at $50	355.17
1 messenger, 5 months, at $50	250.00
1 messenger, 4 months 11 days, at $55	240.86
1 laborer, 4 months, at $60; 2 months 8 days, at $50	352.90
1 laborer, 12 months, at $45	540.00
Total salaries or compensation	27,716.26

General expenses:

Books	$197.93
Drawings and illustrations	59.20
Electricity	155.04
Freight and hauling	186.64
Furniture	131.83
Manuscript	1,886.36
Miscellaneous	322.13
Postage, telegraph, and telephone	43.18
Printing and binding	159.54
Rental	1,375.00

General expenses—Continued.			
Special services	$719.25		
Specimens	995.11		
Stationery	326.73		
Supplies	455.43		
Travel and field expenses	3,363.43		
		$10,376.80	
Total disbursements			$38,093.06
Balance July 1, 1904			1,906.94

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1903

Balance July 1, 1903, as per last report		$3,489.99

DISBURSEMENTS.

General expenses:		
Books and binding	$301.56	
Drawing and illustrations	65.00	
Freight and hauling	239.07	
Furniture	21.50	
Lighting	93.18	
Miscellaneous	39.73	
Postage, telegraph, and telephone	22.77	
Publications	270.07	
Rental	125.00	
Special services	52.50	
Stationery	493.98	
Supplies	88.11	
Travel and field expenses	575.65	
Total disbursements		2,388.12
Balance July 1, 1904		1,101.87

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1903, as per last report		$220.77

DISBURSEMENTS.

General expenses:		
Books	$14.58	
Freight	7.25	
Miscellaneous	14.74	
Supplies	10.13	
Stationery	43.23	
Travel	124.00	
Total disbursements		213.93
Balance		6.84

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for continuing the preservation, exhibition, and increase of the collections from surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, $180,000, of which sum $5,500 may be used for necessary drawings and illustrations for publications of the National Museum and all other necessary incidental expenses" (sundry civil act, March 3, 1903)	$180,000.00

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Salaries or compensation	$160,730.36		
Special services	1,608.25		
Total salaries and services		$162,338.61	
Miscellaneous:			
Supplies	5,660.11		
Stationery	1,440.31		
Freight and cartage	1,626.39		
Traveling expenses	1,740.62		
Drawings and illustrations	1,053.97		
Total miscellaneous		11,521.40	
Total expenditure to June 30, 1904			173,860.01
Balance July 1, 1904, to meet outstanding liabilities			6,139.99

Analysis of expenditures for salaries or compensation.

[July 1, 1903, to June 30, 1904.]

Scientific staff:	
1 assistant secretary, 12 months, at $258.33	$3,099.96
1 head curator, 12 months, at $291.66	3,499.92
1 head curator, 12 months, at $291.66	3,499.92
1 head curator, 11 months 26 days, at $291.66	3,452.88
1 curator, 12 months, at $100	1,200.00
1 curator, 12 months, at $200	2,400.00
1 curator, 12 months, at $200	2,400.00
1 curator, 11 months 18 days, at $200	2,320.00
1 curator, acting, 2 months 15 days, at $200	500.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $125	1,500.00
1 curator, assistant, 12 months, at $133.33	1,599.96
1 curator, assistant, 12 months, at $116.66	1,399.92
1 curator, assistant, 12 months, at $116.66	1,399.92
1 curator, second assistant, 12 months, at $100	1,200.00

Scientific staff—Continued.		
1 curator, assistant, 9 months 15 days, at $133.33	$1,266.63	
1 curator, assistant, 3 months, at $116.66	349.98	
1 curator, assistant, 2 months 15 days, at $133.33, $333.32; 6 months 15 days, at $100, $650	983.32	
1 aid, 12 months, at $100	1,200.00	
1 aid, 3 months, at $100	300.00	
1 aid, 12 months, at $83.33	999.96	
1 aid, 12 months, at $75	900.00	
1 aid, 12 months, at $60	720.00	
1 aid, 6 months, at $45	270.00	
1 aid, 12 months, at $83.33	999.96	
1 aid, 12 months, at $83.33	999.96	
1 aid, 2 months 15 days, at $50	125.00	
1 aid, 12 months, at $100	1,200.00	
1 aid, 12 months, at $50	600.00	
1 aid, 9 months 24 days, at $83.33	814.48	
1 aid, 9 months 15 days, at $100	948.39	
1 aid, 12 months, at $50	600.00	
1 aid, 2 months 15 days, at $100	250.00	
1 assistant, 1 month 25 days, at $40	72.26	
1 assistant, 1 month, at $60	60.00	
1 assistant, 3 months, at $40	120.00	
1 custodian, 1 month 10 days, at $150	198.39	
		$54,250.81
Preparators:		
1 photographer, 12 months, at $175	2,100.00	
1 modeler, 12 months, at $100	1,200.00	
1 osteologist, 12 months, at $90	1,080.00	
1 plant mounter, 1 month, at $40	40.00	
1 preparator, 3 months, at $55	165.00	
1 preparator, 10 months 9 days, at $60	617.42	
1 preparator, 2 months 27 days, at $40	116.00	
1 preparator, 55 days, at $50	90.22	
1 preparator, 23 days, at $50	38.33	
1 preparator, 3 months, at $90	270.00	
1 preparator, 12 months, at $80	960.00	
1 preparator, 12 months, at $100	1,200.00	
1 preparator, 12 months, at $70	840.00	
1 preparator, 1 month 6 days, at $50	60.00	
1 preparator, 2 months, at $50	100.00	
1 preparator, 12 months, at $60	720.00	
1 preparator, 3 months, at $85, $255; 1,048 hours, at at 50 cents, $524	779.00	
1 preparator, 12 months, at $45	540.00	
1 preparator, 12 months, at $50	600.00	
1 preparator, 4 months 27 days, at $75	365.32	
1 preparator, 9 months 15 days, at $85	807.50	
1 preparator, 9 months 12 days, at $40	376.00	
1 preparator, 12 months, at $90	1,080.00	
1 assistant preparator, 3 months, at $40	120.00	
1 taxidermist, 5 months, at $60	300.00	
1 taxidermist, 12 months, at $100	1,200.00	
1 taxidermist (chief), 12 months, at $125	1,500.00	
		17,264.79

Clerical staff:

1 administrative assistant, 12 months, at $291.66	$3,499.92
1 editor, 12 months, at $167	2,004.00
1 editorial assistant, 10 months 7 days, at $133.33	1,364.41
1 chief of division, 12 months, at $200	2,400.00
1 registrar, 12 months, at $167	2,004.00
1 disbursing clerk, 12 months, at $116.67	1,400.04
1 assistant librarian, 12 months, at $133.33	1,599.96
1 finance clerk, 12 months, at $125	1,500.00
1 property clerk, 12 months, at $90	1,080.00
1 stenographer, 12 months, at $90	1,080.00
1 stenographer, 8 months 27 days, at $175	1,556.56
1 stenographer and typewriter, 6 months 18 days, at $60	394.84
1 stenographer and typewriter, 1 month 7 days, at $60	73.81
1 stenographer and typewriter, 9 months 3 days, at $60	546.00
1 stenographer and typewriter, 12 months, at $83.33	999.96
1 stenographer and typewriter, 4 months 15 days, at $60	270.00
1 stenographer and typewriter, 5 months 8 days, at $50	262.90
1 stenographer and typewriter, 1 month 26 days, at $60	110.32
1 stenographer and typewriter, 1 month 42 days, at $50	119.09
1 stenographer and typewriter, 1 month 18 days, at $50	79.03
1 stenographer and typewriter, 6 months 14 days, at $60	387.10
1 stenographer and typewriter, 20 days, at $50	33.33
1 stenographer and typewriter, 31 days, at $60	61.42
1 stenographer and typewriter, 1 month, at $60	60.00
1 stenographer and typewriter, 4 days, at $60	8.00
1 stenographer and typewriter, 3 months 21 days, at $65	239.03
1 stenographer and typewriter, 4 months 15 days, at $50	225.86
1 stenographer and typewriter, 7 months, at $75, $525; 5 months, at $90, $450	975.00
1 typewriter, 2 months 28 days, at $45	132.00
1 typewriter, 11 months 26 days, at $65	769.52
1 typewriter, 12 months, at $85	1,020.00
1 typewriter, 12 months, at $70	840.00
1 clerk, 12 months, at $100	1,200.00
1 clerk, 12 months, at $35	420.00
1 clerk, 18 days, at $3	54.00
1 clerk, 12 months, at $60	720.00
1 clerk, 12 months, at $75	900.00
1 clerk, 12 months, at $75	900.00
1 clerk, 12 months, at $75	900.00
1 clerk, 9 months, at $50	450.00
1 clerk, 12 months, at $125	1,500.00

Clerical staff—Continued.		
1 clerk, 12 months, at $100	$1,200.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 11 months 23 days, at $40	470.67	
1 clerk, 12 months, at $75	900.00	
1 clerk, 5 months 30 days, at $50	298.81	
1 clerk, 2 months 15 days, at $50	125.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 3 months 22 days, at $60	222.58	
1 clerk, 12 months, at $115	1,380.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 6 months, at $125	750.00	
1 clerk, 10 months 31 days, at $55	605.71	
1 clerk, 10 months 15 days, at $40, $420; 1 month 16 days, at $45, $67.58	487.58	
1 clerk, 7 months, at $50, $350; 5 months, at $75, $375	725.00	
1 cataloguer, 11 months 7 days, at $60	673.55	
1 cataloguer, 31 days, at $40	40.27	
1 cataloguer, 2 months 5 days, at $50	108.33	
		$47,167.60
Buildings and labor:		
1 superintendent, 1 month 11 days, at $250	338.71	
1 general foreman, 12 months, at $122.50	1,470.00	
1 captain of watch, 12 months, at $90	1,080.00	
1 lieutenant of watch, 12 months, at $70	840.00	
1 lieutenant of watch, 12 months, at $70	840.00	
1 watchman, 10 months 60 days, at $55	656.46	
1 watchman, 10 months 52 days, at $60	702.32	
1 watchman, 12 months, at $60	720.00	
1 watchman, 5 months 15 days, at $60	330.00	
1 watchman, 6 months 25 days, at $55	374.35	
1 watchman, 7 months 18 days, at $55	419.14	
1 watchman, 12 months, at $55	660.00	
1 watchman, 1 month 30 days, at $50	98.39	
1 watchman, 9 months 15 days, at $60	570.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 3 months 18 days, at $55	196.94	
1 watchman, 1 month 25 days, at $55	100.83	
1 watchman, 2 months 3 days, at $55	115.50	
1 watchman, 5 months 15 days, at $55, $302.50; 6 months 16 days, at $60, $390.08	692.58	
1 watchman, 4 months 17 days, at $55	251.17	
1 watchman, 11 months 21 days, at $55	642.26	
1 watchman, 12 months, at $55	660.00	
1 watchman, 3 months 29 days, at $55	218.17	
1 watchman, 1 month 16 days, at $60	90.97	
1 watchman, 7 months 15 days, at $55	413.45	
1 watchman, 12 months, at $40	480.00	

Buildings and labor—Continued.

1 watchman, 4 months, at $55, $220; 8 months, at $60, $480	$700.00
1 watchman, 4 months, at $55, $220; 8 months, at $60, $480	700.00
1 watchman, 4 months 4 days, at $55	227.33
1 watchman, 11 months, at $55	605.00
1 watchman, 12 months, at $55	660.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $65	780.00
1 watchman, 12 months, at $55	660.00
1 watchman, 5 months 30½ days, at $60	359.03
1 skilled laborer, 9 months, at $40	360.00
1 skilled laborer, 12 months, at $40	480.00
1 skilled laborer, 4 months 29 days, at $60	298.00
1 skilled laborer, 6 months 16 days, at $55	357.42
1 skilled laborer, 12 months, at $55	660.00
1 skilled laborer, 12 months, at $50	600.00
1 skilled laborer, 311 days, at $1.50	468.00
1 skilled laborer, 1 month 26 days, at $50	93.06
1 skilled laborer, 12 months, at $50	600.00
1 workman, 312½ days, at $1.50	468.75
1 laborer, 4½ days, at $1.50	6.75
1 laborer, 314 days, at $1.50	471.00
1 laborer, 19 days, at $1.50	28.50
1 laborer, 12 months, at $45	540.00
1 laborer, 313½ days, at $1.50	470.25
1 laborer, 72 days, at $1.50	108.00
1 laborer, 12 months, at $40	480.00
1 laborer, 5 days, at $1.50	7.50
1 laborer, 314 days, at $1.50	471.00
1 laborer, 103 days, at $1.75	180.26
1 laborer, 314½ days, at $1.50	471.75
1 laborer, 77½ days, at $1.50	116.25
1 laborer, 72 days, at $1.50	108.00
1 laborer, 30 days, at $45	45.25
1 laborer, 83 days, at $1.50	124.50
1 laborer, 11 days, at $1	11.00
1 laborer, 6 days, at $40, $7.74; 13 days, at $1.50, $19.50	27.24
1 laborer, 316½ days, at $1.50	474.75
1 laborer, 42¾ days, at $1.50	64.13
1 laborer, 5 days, at $1.50	7.50
1 laborer, 318 days, at $1.50	477.00
1 laborer, 142½ days, at $1.75	249.38
1 laborer, 165 days, at $1.75, $288.76; 116 days, at $1.50, $174	462.76
1 laborer, 12 months, at $35	420.00
1 laborer, 64½ days, at $1.50	96.75
1 laborer, 36 days, at $1	36.00
1 laborer, 35 days, at $1.50	52.50
1 laborer, 5 days, at $1.50	7.50
1 laborer, 9 months 15 days, at $25	237.50

Buildings and labor—Continued.

1 laborer, 333 days, at $1.50	$499.50	
1 laborer, 314 days, at $1.50	471.00	
1 laborer, 308½ days, at $1.50	462.75	
1 laborer, 343 days, at $1.50	514.50	
1 laborer, 12 months, at $40	480.00	
1 laborer, 11 months 16 days, at $45, $517.58; 15 days, at $40, $20	537.58	
1 laborer, 12 months, at $40	480.00	
1 laborer, 314 days, at $1.50	471.00	
1 laborer, 3 days, at $1.50	4.50	
1 laborer, 10 months 20 days, at $40	426.20	
1 laborer, 314 days, at $1.50	471.00	
1 laborer, 314 days, at $1.50	471.00	
1 laborer, 20½ days, at $40	26.45	
1 laborer, 4 days, at $1.25	5.00	
1 messenger, 4 months 15 days, at $20, $90; 7 months 15 days, at $35, $262.50	352.50	
1 messenger, 7 months, at $30	210.00	
1 messenger, 3 months 3 days, at $20	61.94	
1 messenger, 2 months 20 days, at $20	53.33	
1 messenger, 2 months 19 days, at $20	52.67	
1 messenger, 2 months 41 days, at $25	88.00	
1 messenger, 1 month 20 days, at $20	32.90	
1 messenger, 9 months 28 days, at $20	198.67	
1 messenger, 2 days, at $20	1.38	
1 messenger, 5 months, at $20	100.00	
1 messenger, 23 days, at $20	15.23	
1 messenger, 1 month 33 days, at $20	41.35	
1 messenger, 2 months 30 days, at $25	75.03	
1 messenger, 1 month 29 days, at $25	49.66	
1 messenger, 6 months 3 days, at $20, $121.94; 5 months, at $30, $150	271.94	
1 messenger, 12 months, at $35	420.00	
1 messenger, 1 month 37 days, at $20	43.87	
1 messenger, 37½ days, at $1	37.50	
1 messenger, 9 days, at $1	9.00	
1 messenger, 1 month 7 days, at $20	24.52	
1 mail carrier, 12 months, at $45	540.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 2 months 18½ days, at $30	78.50	
1 cleaner, 9 months 85 days, at $35	413.14	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 2 months 49 days, at $30	108.10	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 11 months 28 days, at $30	357.10	
1 attendant, 12 months, at $40	480.00	
1 attendant, 157 days, at $1	157.00	
1 attendant, 335 days, at $1.50	502.50	
		$42,047.16
Total services		160,730.36

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1903.

RECEIPTS.

Balance as per report July 1, 1903			$9,597.20

EXPENDITURES.

Salaries or compensation	$8.00		
Special services	1,182.81		
Total services		$1,190.81	
Miscellaneous:			
Supplies	5,167.98		
Stationery	1,216.16		
Freight and cartage	582.40		
Traveling expenses	182.90		
Drawings and illustrations	856.72		
Total miscellaneous expenditure		8,006.16	
Total expenditure to June 30, 1904			9,196.97
Balance July 1, 1904			400.23

PRESERVATION OF COLLECTIONS, 1903.

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1904.]

RECEIPTS.

Appropriation by Congress, March 3, 1901			$180,000.00

EXPENDITURES.

Salaries or compensation	$162,216.04		
Special services	2,283.26		
Total services		$164,499.30	
Miscellaneous:			
Drawings and illustrations	2,629.71		
Supplies	8,139.07		
Stationery	8,055.35		
Travel	529.79		
Freight	1,746.55		
Total miscellaneous expenditure		15,100.47	
Total expenditure to June 30, 1904			179,599.77
Balance July 1, 1904			400.23

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1902.

Balance as per report July 1, 1903		$159.16

EXPENDITURES.

Supplies	$74.48	
Freight and cartage	26.04	
Total expenditure to June 30, 1904		100.52
		58.64

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

PRESERVATION OF COLLECTIONS, 1902.

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1904.]

RECEIPTS.

Appropriation by Congress, March 3, 1901			$180,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1904.]

Salaries or compensation	$161,897.99		
Special services	2,255.36		
Total services		$164,153.35	
Miscellaneous:			
Drawings and illustrations	$2,787.83		
Supplies	6,608.47		
Stationery	2,663.02		
Travel	2,021.21		
Freight	1,707.48		
Total miscellaneous expenditures		15,788.01	
Total expenditure to June 30, 1904			179,941.36
Balance			58.64

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, for "cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" (sundry civil act, March 3, 1903)			$22,500.00

EXPENDITURES.

Salaries or compensation	$9,915.81		
Special services	53.25		
Total salaries and services		$9,969.06	
Miscellaneous:			
Storage cases	2,256.26		
Drawings	50.88		
Drawers, trays, boxes	2,200.53		
Frames, stands, miscellaneous woodwork	160.40		

Miscellaneous—Continued.

Glass	$718.26		
Hardware	807.48		
Tools	54.73		
Cloth, cotton, etc	167.60		
Lumber	1,370.44		
Paints, oils, glue, brushes	181.96		
Office and hall furniture and furnishings	939.65		
Leather, rubber, etc	227.95		
Slate	20.42		
Flour	2.40		
Total miscellaneous		$9,098.96	
Total expenditure to June 30, 1904			$19,068.02
Balance July 1, 1904, to meet outstanding liabilities			3,431.98

Analysis of expenditures for salaries or compensation.

[July 1, 1903, to June 30, 1904.]

1 superintendent, 2 months 12 days, at $166.66	$397.82
1 supervisor of construction, 3 months 19 days, at $140	505.81
1 clerk, 10 months 46 days, at $100	1,151.51
1 shop foreman, 12 months, at $85	1,020.00
1 carpenter, 92 days, at $3	276.00
1 carpenter, 4 days, at $3	12.00
1 carpenter, 73 days, at $3	219.00
1 carpenter, 130 days, at $3	390.00
1 carpenter, 4 days, at $3	12.00
1 carpenter, 118 days, at $3	354.00
1 carpenter, 13 days, at $3	39.00
1 carpenter, 24 days, at $3	72.00
1 carpenter, 15½ days, at $3	46.50
1 carpenter, 300 days, at $3	900.00
1 carpenter, 24 days, at $3	72.00
1 skilled laborer, 11 months 29 days, at $65	777.83
1 skilled laborer, 7 months, at $90	630.00
1 skilled laborer, 18 days, at $3	54.00
1 skilled laborer, 18 days, at $3	54.00
1 skilled laborer, 12 months, at $62.50	750.00
1 skilled laborer, 111½ days, at $3	334.50
1 skilled laborer, 127½ days, at $2.25	286.88
1 painter, 11 months 28½ days, at $75	893.95
1 workman, 314 days, at $2	628.00
1 laborer, 26 days, at $1.50	39.00
Total	9,915.81

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1903.

RECEIPTS.

Balance, as per report July 1, 1903 .... $1,696.24

EXPENDITURES.

Miscellaneous:		
Drawers, trays, boxes	$288.98	
Frames, stands, miscellaneous woodwork	31.75	
Glass	335.72	
Hardware	231.49	
Cloth, cotton, etc	28.55	
Lumber	316.95	
Paints, oils, etc	187.79	
Office and hall furniture, etc	210.65	
Rubber, leather, etc	9.11	
Plumbing material	.75	
Slate	41.92	
Total expenditure to June 30, 1904		$1,683.66
Balance July 1, 1904		12.58

Total statement of receipts and expenditures.

[July 1, 1902, to July 1, 1904.]

RECEIPTS.

Appropriation by Congress, June 28, 1902 .... $22,500.00

EXPENDITURES.

Salaries	$12,342.35		
Special services	14.60		
Total services		$12,356.95	
Miscellaneous:			
Cases, storage	$2,266.00		
Cases, exhibition	881.00		
Drawers, trays, etc	1,133.50		
Frames and woodwork	775.66		
Glass	787.76		
Hardware	665.15		
Tools	17.48		
Cloth	65.68		
Lumber	907.74		
Paints, oils, etc	447.41		
Office and hall furniture	1,689.03		
Leather, rubber, cork	274.44		
Drawings	4.00		
Slate	100.72		
Travel	114.15		
Plumbing material	.75		
Total miscellaneous expenditure		10,130.47	
Total expenditure to June 30, 1904			22,487.42
Balance July 1, 1904			12.58

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1902.

RECEIPTS.

Balance as per report July 1, 1903	$5.07

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—HEATING, LIGHTING, ETC., 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, March 3, 1903)	$18,000.00

EXPENDITURES.

Salaries or compensation	$7,681.19		
Special services	118.75		
Total salaries and services		$7,799.94	
Miscellaneous:			
Coal and wood	4,984.00		
Gas	790.60		
Electricity	1,428.36		
Telephones	503.91		
Electrical supplies	627.43		
Rental of call boxes	110.00		
Heating supplies	921.38		
Telegrams	18.80		
Total miscellaneous expenditure		9,384.48	
Total expenditure to June 30, 1904			17,184.42
Balance July 1, 1904, to meet outstanding liabilities			815.58

Analysis of expenditures for salaries or compensation.

[July 1, 1903, to June 30, 1904.]

1 engineer, 12 months, at $122.50	$1,470.00
1 telephone operator, 12 months, at $50	600.00
1 telephone operator, 32 days, at $1.50	48.00
1 telephone operator, 6 days, at $1.50	9.00
1 telephone operator, 5 days, at $1.50	7.50
1 telephone operator assistant, 2 months 31 days, at $45	135.19
1 electrician, 66 days, at $4	264.00
1 blacksmith, 2 months 3 days, at $60	126.00
1 skilled laborer, 5 months, at $90	450.00
1 skilled laborer, 12 months, at $75	900.00
1 skilled laborer, 317¾ days, at $3	953.25
1 plumber's assistant, 316¾ days, at $2.25	712.69
1 fireman, 12 months, at $60	720.00
1 fireman, 52 days, at $60	101.98

1 fireman, 4 months 50 days, at $60	$338.32
1 laborer, 326½ days, at $1.50	489.76
1 laborer, 237 days, at $1.50	355.50
Total	7,681.19

NATIONAL MUSEUM—HEATING AND LIGHTING, 1903.

RECEIPTS.

Balance as per report July 1, 1903	$1,962.63

EXPENDITURES.

Special services	$194.75		
Total salaries or services		$194.75	
Miscellaneous:			
Coal and wood	621.36		
Gas	63.70		
Electricity	119.33		
Telephones	171.65		
Electrical supplies	296.97		
Rental of call boxes	30.00		
Heating supplies	443.61		
Telegrams	9.40		
Total miscellaneous expenditure		1,756.02	
Total expenditure to June 30, 1904			1,950.77
Balance July 1, 1904			11.86

Total statement of receipts and expenditures.

[July 1, 1902, to June 30, 1904.]

RECEIPTS.

Appropriation by Congress, June 28, 1902	$18,000.00

EXPENDITURES.

Salaries or compensation	$8,224.02		
Special services	228.91		
Total services		$8,452.93	
Miscellaneous:			
Coal and wood	4,529.47		
Gas	996.40		
Rental of call boxes	120.00		
Electrical supplies	487.18		
Electricity	1,374.38		
Heating supplies	1,308.35		
Telegrams	47.83		
Telephones	671.60		
Total miscellaneous		9,535.21	
Total expenditure			17,988.14
Balance July 1, 1904			11.86

NATIONAL MUSEUM—HEATING AND LIGHTING, 1902.

Balance, as per report July 1, 1903	$1.60

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—POSTAGE, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "For postage stamps and foreign postal cards for the National Museum" (sundry civil act, March 3, 1903)	$500.00

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

For postage	500.00

NATIONAL MUSEUM—PRINTING AND BINDING, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for the Smithsonian Institution, for printing labels and blanks, and for the 'Bulletins' and 'Proceedings' of the National Museum, the editions of which shall not be less than 3,000 copies, and binding, in half turkey, or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum library" (sundry civil act, March 3, 1903)		$17,000.00

EXPENDITURES.

Bulletins of the Museum	$2,797.57	
Proceedings of the Museum	13,561.44	
Labels	153.96	
Blanks and circulars	268.74	
Congressional Record	38.00	
Binding	177.50	
Total expenditure to June 30, 1904		16,997.21
Balance July 1, 1904		2.79

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, March 3, 1903)	$4,400.00

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Rent of workshops:		
431 Ninth street SW	$1,999.92	
217 Seventh street SW	1,080.00	
309 and 313 Tenth street SW	960.00	
915 Virginia avenue (rear)	360.00	
Total expenditure to June 30, 1904		$4,399.92
Balance July 1, 1904		.08

NATIONAL MUSEUM—RENT OF WORKSHOP, 1903.

Balance as per report July 1, 1903	$0.08
Balance July 1, 1904	.08

NATIONAL MUSEUM—RENT OF WORKSHOP, 1902.

Balance as per report July 1, 1903	$0.08

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—BUILDING REPAIRS, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, March 3, 1903)	$15,000.00

EXPENDITURES.

Salaries or compensation	$9,960.86		
Special services	50.00		
Total salaries and services		$10,010.86	
Miscellaneous:			
Repairs to roofs (by contract)	1,033.26		
Galvanized-iron ceiling cornice	486.78		
Lumber	93.32		
Cement, plaster, mortar, brick, sand, etc	86.45		
Hardware, tools, etc	298.38		
Paints, oils, glue, brushes	275.97		
Skylight	63.60		
Glass	41.25		
Drawings	46.00		
Cloth, etc	270.00		
Terrazzo pavement	66.00		
Plumbing material	11.21		
Rubber, etc	15.90		
Total miscellaneous expenditure		2,520.82	
Total expenditure to June 30, 1904			12,531.68
Balance July 1, 1904, to meet outstanding liabilities			2,468.32

Analysis of expenditures for salaries or compensation.

[July 1, 1903, to June 30, 1904.]

1 superintendent, 6 months, at $166.66	$999.96
1 clerk, 2 months 20 days, at $60	160.00
1 foreman, 9 months 35 days, at $85	861.60
1 carpenter, 314 days, at $3	942.00
1 carpenter, 314 days, at $3	942.00
1 carpenter, 30 days, at $3	90.00
1 skilled laborer, 16 days, at $3	48.00
1 skilled laborer, 56 days, at $1.75	98.00
1 skilled laborer, 16 days, at $3	48.00
1 skilled laborer, 59½ days, at $70	136.57
1 skilled laborer, 76 days, at $3	228.00
1 skilled laborer, 54½ days, at $3	163.50
1 skilled laborer, 31 days, at $1.75, $54.25; 13 days, at $1.50, $19.50	73.75
1 skilled laborer, 10 days, at $3	30.00
1 skilled laborer, 37 days, at $3	111.00
1 skilled laborer, 68 days, at $3	204.00
1 skilled laborer, 11 months 28 days, at $70	833.23
1 skilled laborer, 1 month 54½ days, at $70	194.87
1 classified laborer, 326½ days, at $2	653.00
1 tinner, 1 month 15½ days, at $70	105.00
1 tinner, 3 months 18 days, at $70	250.65
1 tinner, 46 days, at $70	105.98
1 painter's assistant, 314 days, at $1.75	549.50
1 plasterer's assistant, 41 days, at $2	82.00
1 messenger, 7 months, at $20, $140; 5 months, at $30, $150	290.00
1 laborer, 41 days, at $1.50	61.50
1 laborer, 63½ days, at $1.50	95.25
1 laborer, 319½ days, at $1.50	479.25
1 laborer, 86 days, at $1.75	150.50
1 laborer, 314 days, at $1.75	549.50
1 laborer, 221 days, at $1.75	386.75
1 laborer, 13 days, at $1.50	19.50
1 laborer, 12 days, at $1.50	18.00
Total	9,960.86

NATIONAL MUSEUM—BUILDING REPAIRS, 1903.

RECEIPTS.

Balance as per report July 1, 1903	$1,528.97

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Salaries or compensation	$7.00	
Special services	10.00	
Total salaries or services		$17.00
Miscellaneous:		
Lumber	104.41	
Cement, plaster, mortar, gravel, sand, etc	113.25	

Miscellaneous—Continued.			
Hardware, tools, etc	$455.19		
Paints, oils, glue, chemicals	436.17		
Woodwork	11.25		
Skylights	251.30		
Glass	81.31		
Cloth, etc	1.05		
Total miscellaneous expenditure		$1,453.93	
Total expenditure to June 30, 1904			$1,470.93
Balance July 1, 1904			58.04

Total statement of receipts and expenditures.

[July 1, 1902, to June 30, 1904.]

RECEIPTS.

Appropriations by Congress, June 28, 1902	$15,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1904.]

Salaries or compensation	$10,174.89		
Special services	309.80		
Total services		$10,484.69	
Miscellaneous:			
Lumber	552.31		
Cement, plaster, gravel, lime, sand, mortar	319.26		
Hardware, tools, etc	719.32		
Paints, oils, glue, brushes	941.87		
Woodwork	97.23		
Skylights and ventilators	679.30		
Glass	166.16		
Cloth, cotton, etc	2.55		
Paper	40.50		
Drawings	35.00		
Slating roof	750.00		
Steel beams	47.77		
Brickwork	106.00		
Total miscellaneous		4,457.27	
Total expenditure to June 30, 1904			14,941.96
Balance July 1, 1904			58.04

NATIONAL MUSEUM—BUILDING REPAIRS, 1902.

Balance as per report July 1, 1903	$27.23

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—GALLERIES, 1902.

Balance as per report July 1, 1903	$1.17

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—BOOKS, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for purchase of books, pamphlets, and periodicals for reference in the National Museum" (sundry civil act of Congress, March 3, 1903)	$2,000.00

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Books, pamphlets, and periodicals	1,227.60
Balance July 1, 1904, to meet outstanding liabilities	772.40

NATIONAL MUSEUM—BOOKS, 1903.

RECEIPTS.

Balance as per report July 1, 1903	$606.62

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

For books, pamphlets, etc	556.86
Balance July 1, 1904	49.76

NATIONAL MUSEUM—BOOKS, 1902.

RECEIPTS.

Balance as per report July 1, 1903	$198.27

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Books, pamphlets, and periodicals	165.89
Balance	32.38

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for purchase of specimens to supply deficiencies in the collections of the National Museum" (sundry civil act, March 3, 1903)	$10,000.00

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

For purchase of specimens	$8,517.73
Balance July 1, 1904, to meet outstanding liabilities	1,482.27

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1903.

RECEIPTS.

Balance as per report July 1, 1903	$4,000.69

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

For purchase of specimens	3,650.51
Balance July 1, 1904	350.18

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1902.

RECEIPTS.

Balance as per report July 1, 1903	$55.26

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

For specimens	20.00
Balance	35.26

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

NATIONAL MUSEUM—PUBLICATION CONTRIBUTIONS TO NATIONAL HERBARIUM, 1903.

RECEIPTS.

Balance as per report July 1, 1903	$3,972.51

EXPENDITURES.

[July 1, 1903, to June 30, 1904.]

Printing contributions	3,969.80
Balance July 1, 1904	2.71

NATIONAL MUSEUM—PLANS FOR ADDITIONAL BUILDING, NATIONAL MUSEUM, 1903.

Balance as per report July 1, 1903	$43.20
Balance July 1, 1904	43.20

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding 1,500 copies, repairs and alterations of buildings, and miscellaneous expenses, $15,000" (sundry civil act, March 3, 1903)	$15,000.00

DISBURSEMENTS.

Salaries or compensation:			
1 aid, 12 months, at $200	$2,400.00		
1 junior assistant, 12 months, at $125	1,500.00		
1 clerk, 1 month	125.00		
1 stenographer, 11 months, at $100	1,100.00		
1 photographer's assistant, 2 months, at $70	140.00		
1 instrument maker, 12 months, at $90	1,080.00		
1 fireman, 12 months, at $60	720.00		
1 laborer, 12 months, at $25	300.00		
1 carpenter, 13 days, at $3.50	45.50		
1 carpenter, 4 days, at $3	12.00		
1 carpenter, ½ month, at $91	45.50		
1 cleaner, 18 days, at $1	18.00		
1 cleaner, 152 days, at $1	152.00		
Total salaries or compensation		$7,638.00	
General expenses:			
Apparatus	1,949.10		
Books and binding	211.32		
Building repairs	200.00		
Drawings	9.00		
Castings	32.29		
Electricity	143.60		
Freight	9.55		
Lumber	27.41		
Paints, etc	7.23		
Sand	15.00		
Stationery	14.80		
Supplies	315.33		
Travel	60.85		
		2,995.48	
Total disbursements			$10,638.48
Balance July 1, 1904			4,366.52

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1903.

Balance July 1, 1903, as per last report		$1,415.71

DISBURSEMENTS.

General expenses:		
Apparatus	$1,139.80	
Books and binding	102.21	
Castings	8.95	
Drawings	16.34	
Electricity	25.75	
Freight	18.44	
Lighting	1.30	
Supplies	94.90	
Total disbursements		1,407.69
Balance		8.02

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1903, as per last report	$1,323.22

DISBURSEMENTS.

General expenses:	
Apparatus	1,320.00
Balance	3.22

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

OBSERVATION OF ECLIPSE OF MAY 28, 1900.

Balance July 1, 1903, as per last report	$755.74

DISBURSEMENTS.

General expenses:	
Supplies	43.45
Balance	712.29

NATIONAL ZOOLOGICAL PARK, 1904.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1904, "for continuing the construction of roads, walks bridges, water supply, sewerage, drainage, and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistance, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals; the printing and publishing of operations, not exceeding 1,500 copies, and general incidental expenses not otherwise provided for, $95,000" (sundry civil act, March 3, 1903)	$95,000.00

DISBURSEMENTS.

Salaries or compensation:	
1 superintendent, 4 months, at $225; 8 months at $275	$3,100.00
1 property clerk, 8 months, at $150; assistant superintendent, 4 months, at $166.66	1,866.64
1 stenographer, 12 months, at $83.33	999.96
1 clerk, 8 months at $110; 4 months, at $125	1,380.00
1 clerk, 12 months, at $110	1,320.00
1 messenger, 8 months and 13 days, at $30	252.58
1 photographer, 6 months, at $70	420.00
1 landscape gardener, 11½ months and 14½ days, at $83.33	998.47
1 head keeper, 12 months, at $112.50	1,350.00
1 keeper, 12 months, at $60	720.00
1 keeper, 12 months, at $60	720.00
1 keeper, 10 months and 28¼ days, at $60	686.50
1 keeper, 11½ months and 5 days, at $60	700.00

Salaries or compensation—Continued.		
1 sergeant of watch, 9½ months and 34 days, at $65	$690.60	
1 watchman, 1 month, at $60	60.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 6 months, at $55; 6 months, at $60	690.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, ½ month and 19 days, at $50	55.64	
1 machinist, 12 months, at $83.33	999.96	
1 assistant foreman, 12 months, at $65	780.00	
1 assistant blacksmith, 12 months, at $60	720.00	
1 workman, 12 months, at $60	720.00	
1 workman, 12 months, at $60	720.00	
1 laborer, 11 months and 2 days, at $60	663.87	
1 laborer, 6 months, at $55; 6 months, at $60	690.00	
1 laborer, 6 months, at $50; 6 months, at $60	660.00	
Total salaries or compensation		$23,404.22
Miscellaneous:		
Buildings	4,514.62	
Building material	1,438.01	
Fencing, cage material, etc	200.33	
Food	12,860.47	
Freight and transportation of animals	601.71	
Fuel	1,270.73	
Furniture	12.25	
Lumber	567.19	
Machinery, tools, etc	300.03	
Miscellaneous supplies	969.68	
Paints, oils, glass, etc	197.87	
Postage, telegraph, and telephone	95.65	
Purchase of animals	3,054.65	
Road material and grading	374.67	
Stationery, books, etc	229.26	
Surveying, plans, etc	16.50	
Travel and field expenses	168.79	
Trees, plants, etc	15.50	
Water supply, sewerage, etc	230.38	
Total miscellaneous		27,118.29
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:		
1 carpenter, 313½ days, at $3	940.50	
1 workman, 366 days, at $2	732.00	
1 laborer, 96¼ days, at $2.50	240.63	
1 laborer, 300½ days, at $2	601.00	
1 laborer, 367¾ days, at $2	735.50	
1 laborer, 348 days, at $2	696.00	

Wages of mechanics and laborers, etc.—Cont'd.

1 laborer, 375 days, at $2	$750.00
1 laborer, 24½ days, at $1.75	42.87
1 laborer, 340 days, at $1.75	595.01
1 laborer, 245 days, at $1.75; 123¼ days, at $2	675.25
1 laborer, 308½ days, at $1.75	539.88
1 laborer, 366½ days, at $1.75	641.38
1 laborer, 316¾ days, at $1.75	554.32
1 laborer, 371¾ days, at $1.75	650.57
1 laborer, 282¼ days, at $1.75	493.94
1 laborer, 356¼ days, at $1.75	623.44
1 laborer, 294½ days, at $1.75	515.39
1 laborer, 339¾ days, at $1.75	594.57
1 laborer, 344½ days, at $1.75	602.89
1 laborer, 370½ days, at $1.75	648.39
1 laborer, 27 days, at $1.50	40.50
1 laborer, 65¼ days, at $1.50	97.88
1 laborer, 105¾ days, at $1.50	158.63
1 laborer, 45¼ days, at $1.50	67.88
1 laborer, 12 days, at $1.50	18.00
1 laborer, 34½ days, at $1.50	51.75
1 laborer, 22 days, at $1.50	33.00
1 laborer, 7½ days, at $1.50	11.25
1 laborer, 51¾ days, at $1.50	77.64
1 laborer, 96¼ days, at $1.50	144.38
1 laborer, 43 days, at $1.50	64.50
1 laborer, 76½ days, at $1.50	114.75
1 laborer, 54¼ days, at $1.50	81.38
1 laborer, 77¾ days, at $1.50	116.63
1 laborer, 69½ days, at $1.50	104.25
1 laborer, 30½ days, at $1.50	45.75
1 laborer, 55¾ days, at $1.50	83.63
1 laborer, 108¾ days, at $1.50	163.13
1 laborer, 49 days, at $1.50	73.50
1 laborer, 12 days, at $1.50	18.00
1 laborer, 90 days, at $1.50	135.00
1 laborer, 9¼ days, at $1.50	13.88
1 laborer, 17¾ days, at $1.50	26.63
1 laborer, 33 days, at $1.50	49.50
1 laborer, 26 days, at $1.50	39.00
1 laborer, 3 days, at $1.50	4.50
1 laborer, 197½ days, at $1.50	296.26
1 laborer, 76½ days, at $1.50	114.76
1 laborer, 63¾ days, at $1.50; 309½ days, at $1.75	637.26
1 laborer, 157¼ days, at $1.50	235.88
1 laborer, 53 days, at $1.50; 262½ days, at $1.75	538.88
1 laborer, 339 days, at $1.50	508.50
1 laborer, 115¼ days, at $1.50; 206½ days, at $1.75	534.28
1 laborer, 352 days, at $1.50	528.00
1 laborer, 343½ days, at $1.50	515.27

Wages of mechanics and laborers, etc.—Cont'd.

1 laborer, 46 days, at $1.50; 321 days, at $1.75	$630.75
1 laborer, 344½ days, at $1.50	516.76
1 laborer, 205 days, at $2; 42 days, at $1.50	473.00
1 laborer, 118¼ days, at $1.50	177.38
1 laborer, 296¾ days, at $1.50	445.14
1 laborer, 109 days, at $1.50	163.50
1 laborer, 346¼ days, at $1.50	519.39
1 laborer, 328 days, at $1.50	492.00
1 laborer, 222½ days, at $1.50	333.77
1 laborer, 242½ days, at $1.50	363.76
1 laborer, 294 days, at $1.50	441.00
1 laborer, 195¾ days, at $1.50	293.64
1 laborer, 365¾ days, at $1.50	548.63
1 laborer, 62¾ days, at $1.50; 308¾ days, at $1.75	634.43
1 laborer, 36¾ days, at $1.50	55.13
1 laborer, 303 days, at $1.50	454.52
1 laborer, 73½ days, at $1.50; 164¾ days, at $1.75	398.58
1 laborer, 85¼ days, at $1.50	127.88
1 laborer, 194 days, at $1.50; 154½ days, at $1.75	561.40
1 laborer, 41½ days, at $1.50	62.26
1 laborer, 51 days, at $1	51.00
1 laborer, 38¼ days, at $1	38.25
1 laborer, 366¾ days, at $1	366.75
1 laborer, 52½ days, at $1	52.50
1 laborer, 54 days, at $1; 283½ days, at $1.25	408.38
1 laborer, 127 days, at $1; 209¾ days, at $1.25	389.20
1 attendant, 289 days, at 75 cents	216.75
1 attendant, 69 days, at 75 cents	51.75
1 helper, 33 days, at 75 cents; 38½ days, at $1	63.25
1 helper, 151 days, at 75 cents; 145¾ days, at $1	259.00
1 water boy, 40 days, at 50 cents	20.00
1 stonebreaker, 44 cubic yards, at 60 cents	26.40
1 stonebreaker, 14 cubic yards, at 60 cents	8.40
1 wagon and team, 92 days, at $3.50	322.00
1 wagon and team, 367¾ days, at $3.50	1,287.13
1 wagon and team, 55 days, at $3.50	192.50
1 horse and cart, 1 day, at $1.75	1.75
1 horse and cart, 7 days, at $1.75	12.25
1 horse and cart, 97 days, at $1.75	169.74
1 horse and cart, 2½ days, at $1.75	4.37
1 horse and cart, 120¾ days, at $1.75	211.32
1 horse and cart, 112¾ days, at $1,75	197.32

Wages of mechanics and laborers, etc.—Cont'd.			
1 horse and cart, 32¾ days, at $1.75	$57.31		
1 horse and cart, 73½ days, at $1.75	128.63		
1 horse and cart, 15¾ days, at $1.75	27.56		
1 horse, 337 days, at 50 cents	168.50		
Total wages of mechanics, etc		$30,042.52	
Total disbursements			$80,565.03
Balance July 1, 1904			14,434.97

NATIONAL ZOOLOGICAL PARK, 1903.

Balance July 1, 1903, as per last report		$4,755.04

DISBURSEMENTS.

General expenses:		
Buildings	$104.70	
Fencing, cage material, etc	829.89	
Food	1,246.29	
Freight and transportation of animals	370.50	
Fuel	546.80	
Furniture	3.50	
Lumber	301.52	
Machinery, tools, etc	170.31	
Miscellaneous supplies	252.42	
Paints, oils, glass, etc	65.51	
Postage, telegraph, and telephone	87.67	
Purchase of animals	160.13	
Road material and grading	179.46	
Stationery, books, etc	60.65	
Travel	53.30	
Trees, plants, etc	7.35	
Water supply and sewerage	109.42	
Special services	2.00	
Total disbursements		4,551.42
Balance July 1, 1904		203.62

NATIONAL ZOOLOGICAL PARK, 1902.

Balance July 1, 1903, as per last report	$7.26

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1904.

ELEPHANT HOUSE, NATIONAL ZOOLOGICAL PARK, 1903.

Balance July 1, 1903, as per last report		$64.40

DISBURSEMENTS.

General expenses:		
Building material	$27.09	
Fencing	36.77	
Total disbursements		63.86
Balance July 1, 1904		.54

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1904, appears from the foregoing statements and account books to have been as follows:

SMITHSONIAN INSTITUTION.

From balance of last year, July 1, 1903	$55, 507. 67	
From interest on Smithsonian fund for the year	56, 074. 17	
From interest on West Shore bonds	1, 680. 00	
From sales of publications	353. 37	
From repayments, freight, etc	10, 328. 02	
		$123, 943. 23

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International Exchanges—Smithsonian Institution:		
From balance of 1901–2	$0. 88	
From balance of 1902–3	1, 822. 14	
From appropriation for 1903–4	26, 000. 00	
		27, 823. 02
American Ethnology—Smithsonian Institution:		
From balance of 1901–2	220. 77	
From balance of 1902–3	3, 489. 99	
From appropriation for 1903–4	40, 000. 00	
		43, 710. 76
Preservation of collections—National Museum:		
From balance of 1901–2	159. 16	
From balance of 1902–3	9, 597. 20	
From appropriation for 1903–4	180, 000. 00	
		189, 756. 36
Furniture and fixtures—National Museum:		
From balance of 1901–2	5. 07	
From balance of 1902–3	1, 696. 24	
From appropriation for 1903–4	22, 500. 00	
		24, 201. 31
Heating and lighting—National Museum:		
From balance of 1901–2	1. 60	
From balance of 1902–3	1, 962. 63	
From appropriation for 1903–4	18, 000. 00	
		19, 964. 23
Postage—National Museum:		
From appropriation for 1903–4		500. 00
Printing and binding—National Museum:		
From appropriation for 1903–4		17, 000. 00
Rent of workshops—National Museum:		
From balance of 1901–2	. 08	
From balance of 1902–3	. 08	
From appropriation for 1903–4	4, 400. 00	
		4, 400. 16
Building repairs—National Museum:		
From balance of 1901–2	27. 23	
From balance of 1902–3	1, 528. 97	
From appropriation for 1903–4	15, 000. 00	
		16, 556. 20

Galleries—National Museum:		
From balance July 1, 1903		$1.17
Books—National Museum:		
From balance of 1901–2	$198.27	
From balance of 1902–3	606.62	
From appropriation for 1903–4	2,000.00	
		2,804.89
Purchase of specimens—National Museum:		
From balance of 1901–2	55.26	
From balance of 1902–3	4,000.69	
From appropriation for 1903–4	10,000.00	
		14,055.95
Contributions to National Herbarium—National Museum:		
From balance July 1, 1903		3,972.51
Plans for additional building—National Museum:		
From balance July 1, 1903		43.20
Astrophysical Observatory—Smithsonian Institution:		
From balance of 1901–2	1,323.22	
From balance of 1902–3	1,415.71	
From appropriation for 1903–4	15,000.00	
		17,738.93
Observation of eclipse of May 28, 1900:		
From balance July 1, 1903		755.74
National Zoological Park:		
From balance of 1901–2	7.26	
From balance of 1902–3	4,755.04	
From appropriation for 1903–4	95,000.00	
		99,762.30
Elephant house—National Zoological Park:		
From balance July 1, 1903		64.40

SUMMARY.

Smithsonian Institution	$123,943.23	
Exchanges	27,823.02	
Ethnology	43,710.76	
Preservation of collections	189,756.36	
Furniture and fixtures	24,201.31	
Heating and lighting	19,964.23	
Postage	500.00	
Printing and binding	17,000.00	
Rent of workshops	4,400.16	
Building repairs	16,556.20	
Galleries	1.17	
Books	2,804.89	
Purchase of specimens	14,055.95	
Contributions to National Herbarium	3,972.51	
Plans for additional building	43.20	
Astrophysical Observatory	17,738.93	
Observation of eclipse	755.74	
National Zoological Park	99,762.30	
National Zoological Park—Elephant house	64.40	
		$607,054.36

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1904, each of which bears the approval of the Secretary or, in his absence, of the Acting Secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution.

The quarterly accounts current, the vouchers, and journals have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1905.

Balance July 1, 1904		$46,648.33
Interest due and receivable July 1, 1904	$28,110.00	
Interest due and receivable January 1, 1905	28,110.00	
Interest, West Shore Railroad bonds, due July 1, 1904	840.00	
Interest, West Shore Railroad bonds, due January 1, 1905	840.00	
		57,900.00
Total available for year ending June 30, 1905		104,548.33

Respectfully submitted.

J. B. Henderson,
Alexander Graham Bell,
Robert R. Hitt,
Executive Committee.

Washington, D. C., *January 21, 1905.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION ETC.

[Continued from previous Reports.]

[Fifty-eighth Congress, second session.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancies in the Board of Regents of the Smithsonian Institution, of the class other than Members of Congress, shall be filled by the reappointment of John B. Henderson and Alexander Graham Bell, residents of the city of Washington, whose terms of office expire on January twenty-fourth, nineteen hundred and four. (Approved January 27, 1904; Statutes, XXXIII, 582.)

SMITHSONIAN DEPOSIT [LIBRARY OF CONGRESS].—For custodian, one thousand five hundred dollars; assistant, one thousand two hundred dollars; messenger, seven hundred and twenty dollars; messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Approved March 18, 1904; Statutes, XXXIII, 95.)

EXCHANGE OF PUBLIC DOCUMENTS [LIBRARY OF CONGRESS].—For expenses of exchanging public documents for the publications of foreign governments, one thousand eight hundred dollars. (Approved March 18, 1904; Statutes, XXXIII, 96.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, twenty-seven thousand dollars, and for the fiscal year nine-

teen hundred and six estimates shall be submitted hereunder embracing all sums expended for this service out of other appropriations made by Congress. (Approved April 28, 1904; Statutes, XXXIII, 461.)

NAVAL OBSERVATORY.—For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Approved March 18, 1904; Statutes, XXXIII, 120.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved April 28, 1904; Statutes, XXXIII, 461.)

That the Secretary of the Smithsonian Institution is hereby authorized to apply any unexpended balance of the appropriation "American Ethnology, Smithsonian Institution," for the fiscal year ending June thirtieth, nineteen hundred and three, to the payment of liabilities existing against the appropriations "American Ethnology, Smithsonian Institution," for the fiscal years ending June thirtieth, nineteen hundred and one and nineteen hundred and two, respectively, and the same is hereby reappropriated and made available for expenditure for the purpose herein mentioned. (Approved April 27, 1904; Statutes XXXIII, 397.)

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That hereafter the bulletins issued by the Bureau of American Ethnology shall be in octavo size instead of royal octavo. (Approved March 29, 1904; Statutes, XXXIII, 585.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs

and alterations of buildings and miscellaneous expenses, fifteen thousand dollars. (Approved April 28, 1904; Statutes, XXXIII, 461.)

NATIONAL MUSEUM.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty-two thousand five hundred dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum, and all other necessary incidental expenses.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand five hundred and eighty dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars. (Approved April 28, 1904; Statutes XXXIII, 461, 462.)

For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and "Proceedings" of the National Museum, the editions of which shall not be less than three thousand copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum library, twenty-five thousand dollars. (Approved April 28, 1904; Statutes XXXIII, 512.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures and providing seats in the park; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding

one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety-five thousand dollars, one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Approved April 28, 1904; Statutes, XXXIII, 462.)

POWER HOUSE FOR PUBLIC BUILDINGS.

For the preparation, by the superintendent of the library building and grounds, of preliminary plans and estimates of cost for the location, construction, and equipment of a power house with distributing mains for heat, steam, and electric power to the existing and projected Government buildings on the Mall and in the vicinity of the White House, said superintendent to report thereon in full to Congress at its next session, five thousand dollars. (Approved April 28, 1904; Statutes, XXXIII, 511.)

LETTERING OF OFFICIAL VEHICLES.

No part of any money appropriated by this or any other act shall be available for paying expenses of horses and carriages, or drivers therefor, for the personal use of any officer provided for by this or any other act other than the President of the United States, the heads of Executive Departments, and the Secretary to the President: *Provided*, That this provision shall not apply to officials outside of the District of Columbia in the performance of their public duties. This paragraph shall not take effect until July first (nineteen hundred and four. (Approved March 18, 1904; Statutes, XXXIII, 142.)

No part of any money appropriated by this act shall be used for purchase, maintaining, driving, or operating any carriage or other vehicle, other than those authorized for personal purposes in section two of the legislative, executive, and judicial appropriation act for the fiscal year nineteen hundred and five, unless the same shall have conspicuously painted thereon at all times the full name of the Executive Department or other branch of the public service to which the same belong and in the service of which the same are used. (Approved April 28, 1904; Statutes, XXXIII, 513.)

SALARY PAY TABLE.

That the annual compensation of officers, agents, and employees of the United States for services rendered subsequent to June thirtieth, nineteen hundred and four, shall be divided into twelve equal installments, one of which shall be the pay for each calendar month; and in making payments for a fractional part of a month, one-thirtieth of

one of such installments, or of a monthly compensation, shall be the rate to be paid for each day. For the purpose of computing such compensation each and every month shall be held to consist of thirty days, without regard to the actual number of days in any month, thus excluding the thirty-first day of any month from the computation, and treating February as if it actually had thirty days. (Approved April 28, 1904; Statutes, XXXIII, 513.)

RENT OF WORKSHOPS, LOUISIANA PURCHASE EXPOSITION.

GOVERNMENT BOARD, LOUISIANA PURCHASE EXPOSITION: The act of Congress approved June twenty-eighth, nineteen hundred and two, entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred and three, and for other purposes," is hereby amended by inserting at the end and as a part of the paragraph making an appropriation of eight hundred thousand dollars for a Government exhibit at the Louisiana Purchase Exposition to be held in the city of Saint Louis, in the State of Missouri, the following words: "*Provided further*, That the said United States Government Board is authorized to rent such workshops and storage and office rooms in the District of Columbia as may be required for temporary use in connection with the preparation and safe-keeping of the said Government exhibit." And the accounting officers of the Treasury Department are hereby authorized to allow any reasonable expense heretofore incurred by said Government Board in the rental of workshops and storage and office rooms in the District of Columbia for the purpose named. (Approved February 18, 1904; Statutes, XXXIII, 19.)

LEWIS AND CLARK CENTENNIAL EXPOSITION.

AN ACT to authorize the Government of the United States to participate in celebrating the one hundredth anniversary of the exploration of the Oregon country by Captains Meriwether Lewis and William Clark in the years eighteen hundred and four, eighteen hundred and five, and eighteen hundred and six, and for other purposes.

Whereas by an act duly passed by the legislature of the State of Oregon, approved January thirtieth, nineteen hundred and three, said State authorized the holding at the city of Portland, Oregon, commencing May first, nineteen hundred and five, and ending November first, nineteen hundred and five, an industrial exposition to appropriately celebrate the one hundredth anniversary of the exploration of the Oregon country by Captains Meriwether Lewis and William Clark, and "by means of said exhibition to benefit the people of the State of Oregon by way of the advertisement and development of its agricultural, horticultural, mineral, lumber, manu-

facturing, shipping, educational, and other resources" of said State; and

Whereas under and by virtue of said act of the legislature of the State of Oregon a commission consisting of eleven members, residents and inhabitants of said State, was authorized and appointed, known and designated as the Lewis and Clark Centennial Exposition Commission, and the Lewis and Clark Centennial and American Pacific Exposition and Oriental Fair, a corporation organized and existing under the laws of said State, have jointly undertaken the inauguration of the Lewis and Clark Centennial Exposition at said city of Portland, to be held under the joint supervision, control, and management of said commission and corporation, as provided by said act; and

Whereas a number of States have enacted laws for and appropriated money to enable them to participate in said exposition, and other States have signified their intention of so doing, and satisfactory assurances have been given by representatives of foreign governments that their governments will make interesting and instructive exhibits at said exposition illustrative of their material progress during the past century, and it is believed that the commerce of the United States in oriental and oceanic countries will be materially aided and developed by such exposition: Now, therefore, for the purpose of contributing to the success of said exposition and enabling our insular possessions and also oriental and oceanic countries to exhibit of their products and resources at said exposition,

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all articles that shall be imported from foreign countries for the sole purpose of exhibition at said exposition upon which there shall be a tariff or customs duty shall be admitted free of the payment of duty, customs fees, or charges, under such regulations as the Secretary of the Treasury shall prescribe; but it shall be lawful at any time during the exposition to sell for delivery at the close thereof any goods or property imported for and actually on exhibition in the exposition buildings or on the grounds, subject to such regulations for the security of the revenue and for the collection of import duties as the Secretary of the Treasury may prescribe: *Provided*, That all such articles when sold or withdrawn for consumption in the United States shall be subject to the duty, if any, imposed upon such articles by the revenue laws in force at the date of withdrawal, and on articles which shall have suffered diminution or deterioration from incidental handling and necessary exposure the duty, if paid, shall be assessed according to the appraised value at the time of withdrawal for consumption, and the penalties prescribed by law shall be enforced against any person guilty of any illegal sale or withdrawal.

SEC. 2. That there shall be exhibited at said exposition by the Government of the United States from its Executive Departments, the Smithsonian Institution, the National Museum, and the Library of Congress such articles and material as illustrate the function and administrative faculty of the Government in time of peace and its resources as a war power, tending to demonstrate the nature of our institutions and their adaptation to the wants of the people; and the Bureau of American Republics is hereby invited to make an exhibit illustrative of the resources and international relations of the American Republics, and space in the United States Government building shall be provided for that purpose, and to secure a complete and harmonious arrangement of such Government exhibit a United States Government board shall be created, whose duty it shall be to select from the Government exhibit to be made by such Executive Departments at the city of Saint Louis, at the Louisiana Purchase Exposition, in the year nineteen hundred and four, such articles and things as they may deem advisable, and transport the same to the city of Portland, Oregon, to be there exhibited as a part of the Government exhibit at said exposition; and said United States Government board shall also be charged with the selection, purchase, preparation, transportation, arrangement, safe-keeping, exhibition, and return of such additional articles and materials as the heads of the several departments, the Secretary of the Smithsonian Institution, the Director of the National Museum, the Librarian of Congress, and the Director of the Bureau of American Republics may respectively decide shall be embraced in said Government exhibit. And said Government board is hereby authorized to rent and use such building or buildings in the District of Columbia as may be necessary in the preparation of said exhibit. The President of the United States may also designate additional articles for exhibition. Such Government board shall be composed of one person to be named by the head of each of the Executive Departments, one by the head of the Smithsonian Institution and National Museum, one by the Librarian of Congress, and one by the Director of the Bureau of American Republics. The President shall name one of said persons so detailed as chairman, and the board itself shall appoint its secretary, disbursing officer, and such other officers as it may deem necessary. The members of said Government board, with other officers and employees of the Government who may be detailed to assist them, including officers of the Army and Navy, shall receive no compensation in addition to their regular salaries, but they shall be allowed their actual and necessary traveling expenses, together with a per diem in lieu of subsistence, to be fixed by the Secretary of the Treasury, while necessarily absent from their homes engaged upon the business of the board. Officers of the Army and Navy shall receive said allowance in lieu of the subsistence

and mileage now allowed by law; and the Secretary of War and the Secretary of the Navy may, in their discretion, detail retired army or navy officers for such duty. Any provision of law which may prohibit the detail of persons in the employ of the United States to other service than that which they customarily perform shall not apply to persons detailed for duty in connection with said Lewis and Clark Centennial Exposition. Employees of the board not otherwise employed by the Government shall be entitled to such compensation as the board may determine, and such employees may be selected and appointed by said board. The disbursing officer shall give bond in such sum as the Secretary of the Treasury may determine for the faithful performance of his duties, said bond to be approved by said Secretary. The Secretary of the Treasury shall advance to said officer from time to time, under such regulations as the Secretary of the Treasury may prescribe, a sum of money from the appropriation for the Government exhibit herein authorized, not exceeding at any one time three-fourths of the penalty of his bond, to enable him to pay the expenses of said exhibit as authorized by the United States Government board herein created: *Provided*, That so much of the Government exhibit herein authorized as relates to forestry and irrigation shall be made in a separate building, to be erected as hereinafter provided for that purpose, and said building shall be known as the forestry and irrigation building, and shall be of sufficient size to accommodate forestry exhibits other than the United States forestry exhibits: *And provided further*, That the cost of said exhibit herein authorized, including the selection, purchase, preparation, transportation, arrangement, safe-keeping, exhibition, and return of the articles and materials so exhibited, including the forestry and irrigation exhibit, and for rent of building or buildings in the District of Columbia, shall not exceed the sum of two hundred thousand dollars, which amount is hereby appropriated out of any money in the Treasury not otherwise appropriated.

Sec. 3. That the Secretary of the Interior is hereby authorized to aid the inhabitants of the district of Alaska in providing and maintaining an appropriate and creditable exhibit of the products and resources of said district at the said Lewis and Clark Centennial Exposition, and for that purpose he is authorized to appoint one or more persons to supervise the selection, purchase, preparation, transportation, arrangement, installation, safe-keeping, exhibition, and return of such articles as may be exhibited from said district at said exposition; and he is hereby authorized to select so much of the exhibit of the district of Alaska at the Louisiana Purchase Exposition at the city of Saint Louis, in the year nineteen hundred and four, as he may deem necessary for the purpose of making said exhibit at

the Lewis and Clark Centennial Exposition, and that the cost of said exhibit of said district of Alaska, including such selection, purchase, preparation, transportation, arrangement, installation, safe-keeping, exhibition, and return of the articles so exhibited shall not exceed the sum of twenty-five thousand dollars, which sum is hereby appropriated out of any money in the Treasury not otherwise appropriated.

SEC. 4. That the Secretary of the Treasury shall cause a suitable building or buildings to be erected on the site selected for the Lewis and Clark Centennial Exposition for the said Government exhibit, including a suitable building for an exhibit of the United States Life-Saving Service, the forestry and irrigation building herein referred to, and also cause to be erected a suitable building or buildings on said site for the use of the district of Alaska, the Territory of Hawaii, the Philippine Islands, and also oriental and oceanic countries that may desire an exhibit of their products and resources at said exposition. Said buildings shall be erected from plans prepared by the Supervising Architect of the Treasury, to be approved by said United States Government board; and the Secretary of the Treasury is hereby authorized and directed to contract for said buildings in the same manner and under the same regulations as for other public buildings of the United States, but the contract for said buildings and the preparation of grounds therefor and the lighting thereof, inclusive, shall not exceed the sum of two hundred and fifty thousand dollars, which sum is hereby appropriated out of any money in the Treasury not otherwise appropriated. The Secretary of the Treasury is authorized and required to dispose of said buildings, or the materials composing the same, at the close of the exposition, giving preference to the city of Portland, or to the said Lewis and Clark Centennial and American and Pacific Exposition and Oriental Fair corporation, to purchase the same at an appraised value to be ascertained in such manner as the Secretary of the Treasury may determine.

SEC. 5. That the allotment of space for exhibitors in the building or buildings erected under authority of this act for the use of the district of Alaska, the Territory of Hawaii, the Philippine Islands, and also for the use of oriental and oceanic countries, including the space not occupied by the Government board in the forestry and irrigation building, shall be done and performed without charge to exhibitors by the Government board authorized by section two of this act.

SEC. 6. That upon the approval of this act the Secretary of the Treasury shall, upon the request of the Lewis and Clark Centennial and American Pacific Exposition and Oriental Fair Company, cause to be coined at the mints of the United States not to exceed two hundred and fifty thousand gold dollars, of legal weight and fineness, to

be known as the Lewis and Clark Exposition gold dollar, struck in commemoration of said exposition. The words, devices, and designs upon said gold dollars shall be determined and prescribed by the Secretary of the Treasury, and all provisions of law relative to the coinage and legal-tender quality of all other gold coin shall be applicable to the coin issued under and in accordance with the provisions of this act. That the said coins shall be disposed of by the Secretary of the Treasury to the said Lewis and Clark Centennial and American Pacific Exposition and Oriental Fair Company at par, under rules and regulations and in amounts to be prescribed by him. That medals with appropriate devices, emblems, and inscriptions commemorative of said Lewis and Clark Centennial Exposition and of the awards to be made to the exhibitors thereat shall be prepared by the Secretary of the Treasury at some mint of the United States for the board of directors of said exposition company, subject to the provisions of the fifty-second section of the coinage act of eighteen hundred and ninety-three, and upon the payment of a sum not less than the cost thereof; and all provisions, whether penal or otherwise, of said coinage act against the counterfeiting or imitating of coins of the United States shall apply to the medals issued under this act.

SEC. 7. That the United States shall not be liable on account of said exposition for any expense incident to or growing out of the same except for the construction of the building or buildings hereinbefore authorized and for the purpose of paying the expense incident to the selection, preparation, purchase, installation, transportation, care, custody, and safe return of the exhibits made by the Government, and for the employment of proper persons as officers and assistants by the Government board created by this act and for other expenses, and for the maintenance of said building or buildings and other contingent expenses, to be approved by the chairman of the Government board, or, in the event of his absence or disability, by such officer as the board may designate, and the Secretary of the Treasury, upon itemized accounts and vouchers: *Provided*, That no liability against the Government shall be incurred and no expenditure of money appropriated by this act shall be made until the officers of said exposition shall have furnished to the satisfaction of the Secretary of the Treasury proof that there has been obtained for the purpose of completing and opening said exposition bona fide subscriptions to the stock of said exposition company by responsible parties, contributions, donations, or appropriations, from all sources, a sum aggregating not less than six hundred thousand dollars.

SEC. 8. That the United States shall not in any manner or under any circumstances be liable for any of the acts, doings, or representations of said Lewis and Clark Centennial and American Pacific

Exposition and Oriental Fair, or the commission created by the act of the legislature of the State of Oregon, herein referred to, their officers, agents, servants, or employees, or any of them, or for service, salaries, labor, or wages of said officers, agents, servants, or employees, or any of them, or for any subscriptions to the capital stock, or for any stock certificates, bonds, mortgages, or obligations of any kind issued by said corporation or said commission, or for any debts, liabilities, or expenses of any kind or nature whatever attending such exposition corporation or commission, or accruing by reason of the same.

SEC. 9. That nothing in this act shall be construed so as to create any liability upon the part of the United States, direct or indirect, for any debt or obligation incurred, or for any claim for aid or pecuniary assistance from Congress or the Treasury of the United States in support or liquidation of any debts or obligations created by said United States Government board in excess of appropriations hereafter made by Congress therefor. (Approved, April 13, 1904; Statutes, XXXIII, 175.)

REPORT

OF

S. P. LANGLEY,

SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE

YEAR ENDING JUNE 30, 1904.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to present herewith my report, showing the operations of the Institution during the year ending June 30, 1904, including the work placed under its direction by Congress in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, and the Astrophysical Observatory.

Following the precedent of several years, there is given, in the body of this report, a general account of the affairs of the Institution and its bureaus, while the Appendix presents more detailed statements by the persons in direct charge of the different branches of the work. Independently of this, the operations of the National Museum are fully treated in a separate volume of the Smithsonian Report, and the Report of the Bureau of American Ethnology constitutes a volume prepared under the supervision of the Chief of that Bureau. The scientific work of the Astrophysical Observatory is recorded in occasional publications.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an Establishment. Its statutory members are the President, the Vice-President, the Chief Justice of the United States, and the heads of the Executive Departments. The prerogative of the Establishment is "the supervision of the affairs of the Institution and the advice and the instruction of the Board of Regents."

A vacancy continues to exist in the Establishment caused by the succession to the Presidency of Vice-President Roosevelt.

As organized on June 30, 1904, the Establishment consisted of the following ex officio members:

THEODORE ROOSEVELT, *President of the United States.*
(Vacancy), *Vice-President of the United States.*
MELVILLE W. FULLER, *Chief Justice of the United States.*
JOHN HAY, *Secretary of State.*
LESLIE M. SHAW, *Secretary of the Treasury.*
WILLIAM H. TAFT, *Secretary of War.*
PHILANDER C. KNOX, *Attorney-General.*
HENRY C. PAYNE, *Postmaster-General.*
WILLIAM H. MOODY, *Secretary of the Navy.*
ETHAN ALLEN HITCHCOCK, *Secretary of the Interior.*
JAMES WILSON, *Secretary of Agriculture.*
GEORGE B. CORTELYOU, *Secretary of Commerce and Labor.*

ORGANIZATION OF THE BOARD OF REGENTS.

The Board of Regents consists of the Vice-President and the Chief Justice of the United States as ex officio members, three members of the Senate, three members of the House of Representatives, and six citizens, "two of whom shall be residents of the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State."

As organized at the end of the fiscal year, the Board consisted of the following members:

The Hon. M. W. Fuller, Chief Justice of the United States, Chancellor; the Hon. W. P. Frye, President pro tempore of the United States Senate, acting as Regent; Senator S. M. Cullom; Senator O. H. Platt; Senator Francis M. Cockrell; Representative R. R. Hitt; Representative Robert Adams, jr.; Representative Hugh A. Dinsmore; Dr. James B. Angell, of Michigan; Dr. Andrew D. White, of New York; the Hon. J. B. Henderson, of Washington City; Prof. A. Graham Bell, of Washington City; the Hon. Richard Olney, of Massachusetts, and the Hon. George Gray, of Delaware.

MEETINGS OF THE BOARD OF REGENTS.

At a meeting of the Board of Regents held March 12, 1903, the following resolution was adopted:

"*Resolved*, That in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted."

In accordance with the above resolution the Board met on December 8, 1903, January 27, 1904, and March 7, 1904.

The following is an abstract of its proceedings, which latter will be found in the annual report of the Board to Congress:

Regular meeting of December 8, 1903.

Senator Platt and the Chancellor made statements with regard to the new building for the National Museum, and the Secretary read a report which showed that with the advice and consent of the Chancellor and the chairman of the executive committee, as required by the resolution of the Board adopted March 12, 1903, a contract had been made, under date of May 18, 1903, with Messrs. Hornblower & Marshall, architects, of Washington, D. C., for the necessary architectural services.

With regard to the special report of the executive committee as submitted by Doctor Bell, and the report of the special committee which was read at length by the Chancellor, the Board, after discussion, adopted resolutions providing for the printing of these reports and their distribution to the members of the Board.

The Secretary presented the compilation of laws which had been prepared in accordance with a resolution offered by Senator Cockrell at the meeting of March 12, 1903, and the manuscript was referred to Senator Cockrell for his examination and decision as to printing.

The Secretary read letters from the Hon. William Henry Bishop, United States consul at Genoa, Italy, and from the committee of the British burial ground fund, explaining the urgency of action with regard to the removal of the remains of James Smithson.

Doctor Bell renewed the proposition which he made at the last meeting that the remains of Smithson be brought to this country at his expense, and after discussion the Board adopted the following resolutions:

"*Resolved*, That Dr. A. Graham Bell be appointed as a committee to take charge of the matter of the removal of the remains of James Smithson from Genoa to Washington, with the request that the negotiations and removal be conducted quietly and privately.

"*Resolved*, That upon the conclusion of this duty all expenses involved by it be reimbursed to Doctor Bell from the funds of the Institution."

ANNUAL MEETING OF JANUARY 27, 1904.

The Secretary announced that on January 12 the Speaker of the House had reappointed Representatives Hitt, Adams, and Dinsmore as Regents for two years; and also that Senator Henderson and Dr. A. Graham Bell had been reappointed for a term of six years by joint resolution approved by the President January 27, 1904.

The usual resolution relative to income and expenditure was adopted, and the Secretary presented his annual report of the operations of the

Institution and its several dependencies for the fiscal year ending June 30, 1903.

The Board adopted the annual report of the executive committee to the same date, showing in detail the financial condition of the Institution.

Senator Henderson, chairman of the permanent committee, made statements in regard to the proposed bequests of Addison T. Reid and Joseph White Sprague; also concerning the will of Wallace C. Andrews, and the present status of the Hodgkins and Avery funds. He further reported upon the expenditures incurred by the Secretary since the last annual meeting, in continuing his experiments in mechanical flight under the authority of the Board.

The Secretary made a statement concerning the publications in preparation by the Institution and also with regard to aerodromic experiments carried on by him.

He reported that Congress, under a clause of the sundry civil act, approved March 3, 1903, had authorized the erection of a new building for the National Museum at a cost not to exceed $3,500,000.

He spoke of the work of the Bureau of American Ethnology and of his efforts to place the Bureau upon a sound administrative footing. He recalled previous efforts to secure a law for the protection of antiquities on the public domain, and urged present action. The Board thereupon adopted a resolution to that effect.

The Secretary reported upon the work of the International Exchanges, the National Zoological Park, and the Astrophysical Observatory.

The report of the special committee to consider the question of defining the duties of the executive committee was submitted by the Chancellor, but action thereupon was deferred until the meeting of March 7.

At the evening session of this meeting Dr. A. Graham Bell submitted in full his report upon the removal of James Smithson's remains from Genoa to Washington, which is on file with the records of the Board and a lengthy abstract of which will be found on page 7.

After remarks, the Board adopted the following resolutions:

"*Resolved*, That the Board of Regents desire to record in the minutes of the Institution their profound appreciation of the voluntary service of Dr. Alexander Graham Bell in personally going to Genoa and returning with the remains of James Smithson that they might find a resting place in the grounds of the Institution he so nobly founded 'for the increase and diffusion of knowledge among men.'

"*Resolved*, That the Chancellor and the Secretary, with the members of the executive committee, be appointed a committee upon the question of the final disposition of the remains of James Smithson and of the monument to be erected to him, with power to act in the entire matter."

REGULAR MEETING OF MARCH 7, 1904.

The Chancellor read in full the report of the special committee appointed to consider the question of defining the powers of the executive committee, which was very fully discussed and adopted.

Doctor Bell then read the special report of the executive committee as presented by him at the meeting of December 8, 1903. After discussion the Board adopted Senator Cullom's motion that action on the report be indefinitely postponed.

The report of the special committee on the disposition of the remains of James Smithson, in which it was recommended that a fitting tomb should be erected in the grounds of the Institution and that Congress be requested to make an adequate appropriation for it, was submitted. After remarks the report was adopted with the understanding that the committee was to pursue the subject still further.

The Secretary brought before the Board the matter of the will of the late Harriet Lane Johnston, who left a number of paintings to the Corcoran Gallery of Art until a national gallery of art should be established by the Government. The Corcoran Gallery had declined the pictures under these conditions, and the Secretary had been addressed with regard to the probability of the Government establishing such a gallery of art under the Smithsonian Institution. The matter was referred to the executive committee.

GENERAL CONSIDERATIONS.

The Institution has been for more than half a century one of the most important agencies in the intellectual life of the American people. It has furnished a center for workers in every department of scientific and educational activity, and it has been the chief agency for the free exchange of books, apparatus of research, and of scientific intelligence between this and other countries. Its publications, which include more than 250 volumes, are to be found in all of the important libraries of the world, and some of them on the work table of every scientific investigator. Its library constitutes an important part of the Library of Congress, and its museum is the rarest in existence in many branches of the natural history and ethnology of the New World.

For nearly sixty years it has been in constant cooperation with the Government, with public institutions, and with individuals in every enterprise, scientific or educational, which needed its advice, support, or aid. The appreciation of the work of the Institution by the American people is best testified by their representatives in Congress. This has been clearly demonstrated through many successive terms regardless of political change; by the judgment with which their representatives upon the Board of Regents are selected; by the care by which they protect the Institution in its freedom from political entangle-

ments; by the discrimination with which the reports are distributed, and by numerous evidences of interest and liberality.

The objects of the Institution were defined by the founder in the broadest possible terms, and interpreted by its first Secretary, Joseph Henry, in the words "to assist men of science in making original researches, to publish them in a series of volumes, and to give a copy of them to every first-class library on the face of the earth." While the field has been of necessity narrowed from time to time, or diverted in first one direction and then another, the breadth of scope has never been narrowed. That many of the efforts have grown so large as to require either direct support of the Government by the establishment of independent bureaus, finally coming under the direction of the Executive Departments, or aid to agencies which continue under the direction of the Institution, though sustained by Congressional appropriation, is but a further evidence of the fact that the charter of the Institution has been adhered to both in the spirit and in the letter. The United States Weather Bureau, the Geological Survey, the Fish Commission, and the National Herbarium grew out of its earlier activities, and the National Museum, the International Exchanges, the Bureau of American Ethnology, the Zoological Park, and the Astrophysical Observatory are still directed by it. It led the way in the organization of library work in the United States; it took the initial steps and continues to support schemes for international cataloguing, and it maintains a benevolent relation with the American Historical Association and the National Society of the Daughters of the American Revolution.

Sixty years ago it was relatively the best endowed scientific institution in the United States and one of two or three of national scope. The magnificent endowments in this time of so many universities and colleges have changed this relationship to one of pecuniary inferiority, yet without changing the nature of the Institution's relations to these. To the organizations aiding in the scientific advancement of the country, which advancement has in large measure contributed to the material welfare of the United States, the interests benefited thereby have in return made large endowments for original research either through the great universities and societies of the land or by the establishment of new academies, institutions, and museums. To all of these the Smithsonian Institution holds out a friendly cooperation, its aim being, while continuing its own work upon its accepted lines and adapting them to new needs as occasion arises, to continue along the established policy of preventing rivalries, promoting wise cooperation, diminishing waste, and furthering the search for knowledge, the recording of discovered truth, and its dissemination among the people.

It must at no time be forgotten, however, that the Institution, of which the Government is trustee, was not limited either by the founder

or by Congress to the people of the United States, but was designed for all men. The spreading abroad of the work done by scientific men in this country, the bringing to the knowledge of our own workers the researches of men of other lands, the aiding in international congresses which take place from time to time in various countries, the promotion, in short, of friendly relations and useful cooperation among scientific men the world over, and the advice and support to our Government in such relations wherever possible, may be counted in no small measure among the important works which the Institution is carrying on.

THE REMOVAL OF THE REMAINS OF JAMES SMITHSON.

The remains of James Smithson, founder of the Smithsonian Institution, who died June 27, 1829, at Genoa, Italy, were deposited in the little cemetery belonging to the English church, on the heights of San Benigno, a solitary spot planted with cypress trees, and looking down upon the Gulf of Genoa. In 1891 the Secretary of the Institution visited the grave, and, with the approval of the regents, deposited with the secretary of the English church fund a small sum to invest in Italian 5 per cent rents, for its perpetual care. It was visited on two later occasions by the Secretary, who placed a bronze tablet containing a bas-relief of Smithson, in the English church, and one also at the tomb, whence it was subsequently stolen.

In previous reports mention has been made of the suggested removal of the remains of Mr. Smithson to America, in view of the probability that before many years the site of the cemetery might be required by the Italian authorities. In accordance with the resolution of the Regents adopted December 8, 1903 (see p. 3), appointing him a committee to take charge of the removal of the the remains from Genoa to Washington, Dr. Alexander Graham Bell, accompanied by Mrs. Bell, sailed on the 15th of December for the port of Cherbourg in France, and going thence to Genoa, commenced at once the arrangements for the transfer of the remains, arrangements which would have occupied a quite indefinite time and incurred a corresponding delay except for the aid given by the United States consul, Mr. William Henry Bishop, which Dr. Bell gladly acknowledges.

On opening the tomb in the presence of Dr. Bell, the United States consul, Noel Lees, esq. (official representative of the British Burial Ground Fund Association), and other witnesses, it was found that the remains of Smithson, represented by the skeleton, were in fair preservation, although the wooden coffin in which they had been inclosed had molded away. The remains were placed in a metal casket and deposited in the mortuary chapel of the cemetery, where they rested until January 2, when the casket was inclosed in a coffin of strong wood and covered with the American flag by Consul Bishop. On this

occasion Doctor Bell, Mr. Bishop, and the other witnesses again assembled and the following remarks were made:

REMARKS BY WILLIAM HENRY BISHOP, ESQ., UNITED STATES CONSUL.

Dr. Alexander Graham Bell: You arrived, here, my dear Dr. Graham Bell, charged by the Smithsonian Institution with the mission of removing to Washington the remains of the founder of that Institution, James Smithson, who has been buried till now in the cemetery where we stand since his death at Genoa in the year 1829. Having been invited by you and by the Smithsonian Institution to aid you, to what extent I might be able, in this object, it has been a matter of great pride and pleasure to me that I have been allowed to do so.

All the steps necessary to such removal have now been taken. We have received the authorization of the governmental heads of the province, the city, and the British Burial Ground Fund, in which latter the title to the cemetery and the custody of the grave of James Smithson are vested, and all of these have kindly cooperated with us in the work.

The body of James Smithson has now been reverently raised from the earth; it has been placed in a case securely sealed, and this case stands ready to pass into the charge of the steamship company which will convey it to New York.

I assure you that it is with a feeling of real emotion that I have just now cast the American flag over the body of this illustrious man, this noble but as yet little known benefactor, as it is on the verge of beginning its journey to the United States. The flag adopts him already, as it were, in the substance, for our country, to which he has so long belonged in the spirit. He is now about to receive there a portion of the outward veneration and homage he so supremely merits, and which, owing to the modest circumstances of his life, and his interment here in some sense almost forgotten, he has never had.

Shall I admit that on taking possession of my post as consul at Genoa I did not even know who James Smithson was? I may say that I was surprised to learn that he was buried at Genoa; more surprised still that he was an Englishman, who had never even set foot in America. He left his great bequest to the United States, then in its infancy, through admiring confidence in our future. It is likely that many, or even most, Americans are in the same condition as was I myself; for occasion has rarely arisen for taking thought as to the personality of the man. Happily this unenlightened condition of mind is about to cease.

Dr. Graham Bell, I wish you a hearty God-speed across the ocean with your precious freight. The American people will receive it with general gratification, and, through the Smithsonian Institution, will soon delight to pay it great honor.

RESPONSE BY DR. ALEXANDER GRAHAM BELL.

Mr. Consul: It is with feelings of deep emotion that I undertake the transportation of the remains of James Smithson from the cemetery where they have so long reposed to their last resting place in the United States.

On behalf of the Smithsonian Institution allow me to thank you, Mr. Consul, for the unwearied zeal and care with which you have given me your assistance. Without your active cooperation and without your personal sympathy it would have been difficult, indeed, for me to have accomplished the object of my mission here.

On behalf of the Smithsonian Institution I beg to thank you, too, Mr. Noel Lees, for your courtesy and attention, and trust that you will convey to His British Majesty's consul-general and to the committee of the British Burial Ground Fund my thanks, and the thanks of the Institution I represent, for their ready assistance in furthering my mission.

The United States of America will provide, in Washington, D. C., a suitable and permanent resting place for the remains of her great benefactor, James Smithson, through the instrumentality of the Smithsonian Institution, the establishment created by the Government to perpetuate his name.

REMARKS BY NOEL LEES, ESQ.

DR. GRAHAM BELL: I beg to thank you heartily for the words you have said with regard to the aid you have received from the burial board and myself. Although we regret to lose the remains of James Smithson, we at the same time feel that in the country to which he left his money, with such charitable intent, his remains will receive the honor and glory which have so long been due to them, and we must understand that our loss is America's gain. To us it will always remain a pleasant memory that, from the date of his burial to the present day, we have had in our custody in this picturesque little churchyard, the remains of a man whose foresight and kindness have enabled so many in the New World to benefit.

On the conclusion of these remarks the remains were placed on board the steamer *Princess Irene*, of the North German Lloyd Company, which brought them to America in the personal charge of Dr. Bell, the vessel reaching New York on the morning of January 20. By direction of the President of the United States, the U. S. S. *Dolphin* met the *Princess Irene* in the lower bay and escorted her up the harbor.

In the presence of Dr. Bell and the Secretary of the Institution, the remains were transferred to a naval tug and conveyed to the *Dolphin*, and in the continued charge of Dr. Bell were brought to Washington, arriving at the Navy-Yard on Saturday, January 23.

On Monday the 25th the remains were transported by the naval authorities, with suitable ceremonies, to the navy-yard gate, where they were taken in charge by a cavalry escort furnished by the War Department, and, accompanied by Assistant Secretary of State Loomis, representing the President, by the British ambassador, the Regents and the Secretary of the Institution, and the president of the Board of Commissioners of the District of Columbia, they were conveyed to the Smithsonian Institution, where the coffin, draped in the American and British flags, was deposited in the center of the main hall of the building.

Dr. Bell, addressing Senator Frye in behalf of the Regents, said:

MR. SENATOR: I have the honor to hand over to the Smithsonian Institution the mortal remains of its founder, James Smithson, a Fellow of the Royal Society of London, England, who died in Genoa, Italy, on the 27th of June, 1829.

For nearly seventy-five years the body of Smithson has reposed in an almost forgotten grave in the picturesque little British cemetery on the heights of San Beningo, in Genoa. City improvements have led to the expropriation of this cemetery and removal of the remains, and at the last meeting of the board of regents of the Smithsonian Institution I was appointed a committee to arrange for the transfer of the remains of Smithson to this country. On my arrival in Genoa every facility was afforded me for the accomplishment of my mission by the provincial and municipal authorities, by His British Majesty's consul-general, Mr. Keene; by the committee of the British Burial Fund Association, in which is vested the ownership of the

cemetery, as well as by our own consul, Mr. William Henry Bishop, to whom I am much indebted for his valued services.

On the 31st of December, 1903, the tomb of Smithson was opened in my presence, as the representative of the Smithsonian Institution, and in the presence of the American consul and six other witnesses. The remains of Smithson were reverently raised from the grave and placed in a metallic casket, over which the consul of the United States cast the American flag, while the witnesses stood around with uncovered heads. The casket was then left in the mortuary chapel of the cemetery, securely sealed and under guard, until the 2d of January, when it was placed in a coffin of strong wood, as demanded by Italian law, and was then transported to the North German Lloyd steamship *Princess Irene*, accompanied by the American consul and myself.

The steamer sailed from Genoa on the 7th of January, and upon arrival in the United States, the remains of Smithson were received with national honors by direction of the President, and of the Secretary of the Navy and the Secretary of War.

The remains were brought to Washington on board the U. S. dispatch boat *Dolphin*, and have been escorted to the Smithsonian Institution by United States cavalry.

And now, Mr. Senator, my mission is ended, and I deliver into your hands, as the representative of the Board of Regents of the Smithsonian Institution, the remains of this great benefactor of the United States.

Senator Frye replied:

SIR: The Smithsonian Institution receives with profound gratitude the remains of its distinguished founder. Providence, every now and then, seems to place in the world a man and inspires him with a purpose to elevate his fellow men. Such a man was Mr. Smithson, the founder of this Institution. The spirit, sir, which prompted you to such earnest endeavor, resulting as it did in taking these remains from their resting place in a country foreign to him and foreign to us, and bringing them here where for so many years we have enjoyed the rich fruits of his splendid benefaction, your countrymen will appreciate. His grave here will be an incentive to earnest, faithful, wise, and discreet endeavor to carry out his lofty purposes, and, sir, it will be to our people a sacred spot while the Republic endures.

The brief but impressive ceremonies of the occasion concluded with the following prayer, offered by the Rev. Dr. Randolph H. McKim:

Almighty God, eternal source of light and truth, by whose wise providence all things in heaven and earth are governed, we give thee thanks that thou didst put into the heart of thy servant whose dust we receive with reverence here to-day, to lay the foundation of this school of science, and we pray thee that it may more and more be instrumental in the true interpretation of the laws of nature, and in unveiling to the mind of man the glory of God in the work of his hands, to the end that for all the generations to come this Institution may be a beacon light of truth and of progress, to the glory of God and to the good of mankind. All this we beg through Him by whom all things were made, Jesus Christ, our Lord. Amen.

The remains rest temporarily in a room which contains the few personal relics of Smithson, until their final disposal by the Regents.

ADMINISTRATION.

In view of the ever-increasing responsibilities imposed upon the Institution, both by the administration of its own fund and the several dependencies placed by Congress under its direction, a system has been from year to year carefully worked out, which, while retaining

in a central office under the Secretary's supervision, the general plan of the whole Institution, has rendered it practicable to leave the carrying out of details to those in immediate charge of the work of the bureaus. I record with gratitude the ever-increasing aid rendered me by the Regents, as evidenced not only through the increased amount of time given to the policy of the Institution, but by their advice and help in all matters, whether of policy or administration, in which their aid has been sought.

BUILDINGS.

The ceiling of the large anthropological hall in the main Smithsonian building has been practically reconstructed and the hall has been painted and decorated anew. There has thus been practically made available for use the largest single exhibition hall in the building, and it is expected that the valuable archæological collections of the Institution will be seen to better advantage than ever before. It is to be regretted that the uncomfortable tread of the steps and the absence of an elevator may deter many persons from visiting this very attractive room.

The repairs to the roof of the main Smithsonian building have been completed, and much-needed repairs were also made to the roof of the Museum building.

FINANCES.

The permanent funds of the Institution are as follows:

Bequest of Smithson, 1846		$515, 169. 00
Residuary legacy of Smithson, 1867		26, 210. 63
Deposit from savings of income, 1867		108, 620. 37
Bequest of James Hamilton, 1875	$1, 000. 00	
Accumulated interest on Hamilton fund, 1895	1, 000. 00	
		2, 000. 00
Bequest of Simeon Habel, 1880		500. 00
Deposit from proceeds of sale of bonds, 1881		51, 500. 00
Gift of Thomas G. Hodgkins, 1891		200, 000. 00
Portion of residuary legacy of Thomas G. Hodgkins, 1894		8, 000. 00
Deposit from savings of income, 1903		25, 000. 00
Total permanent fund		937, 000. 00

The above fund is deposited in the Treasury of the United States and bears interest at 6 per cent per annum under the provisions of the act organizing the Institution and act of Congress approved March 12, 1894. In addition to the permanent fund, the Regents hold certain approved railroad bonds which form part of the fund established by Mr. Hodgkins for investigations into the properties of atmospheric air.

At the beginning of the fiscal year, July 1, 1903, the balance, as stated in my last report, was $55,507.67. During the year the total receipts by the Institution were $68,435.56. Of this sum, $57,754.17 was derived from the interest and the remaining $10,681.39 was received from miscellaneous sources.

The disbursements during the year amounted to $77,294.90, the details of which are given in the report of the executive committee. The balance remaining to the credit of the Secretary on June 30, 1904, for the expenses of the Institution was $46,648.33. A considerable part of this balance is held against certain contingent obligations which may be expected to mature as a result of various scientific investigations and publications in progress.

During the fiscal year 1904, the Institution was charged by Congress with the disbursement of the following appropriations:

International Exchanges		$26,000
American Ethnology		40,000
Astrophysical Observatory		15,000
United States National Museum:		
Furniture and fixtures	$22,500	
Heating and lighting	18,000	
Preservation of collections	180,000	
Purchase of specimens	10,000	
Postage	500	
Books	2,000	
Rent of workshops	4,400	
Repairs to buildings	15,000	
Printing	17,000	
		269,400
National Zoological Park		95,000
Total		445,400

The following estimates were forwarded, as usual, to the Secretary of the Treasury for carrying on the Government's interests under the charge of the Institution for the fiscal year ending June 30, 1905. This table shows the estimates and sums respectively appropriated:

	Estimates.		Appropriations.	
International Exchanges		$26,000		$27,000
American Ethnology		50,000		40,000
Astrophysical Observatory		15,000		15,000
National Museum:				
Furniture and fixtures	$22,500		$22,500	
Heating and lighting	18,000		18,000	
Preservation of collections	210,000		180,000	
Purchase of specimens	10,000		....	
Books	5,000		2,000	
Postage	500		500	
Building repairs	15,000		15,000	
Rent of workshops	4,580		4,580	
Sunday and night opening	12,000		....	
		297,580		242,580
Building for National Museum		300,000	....	
National Zoological Park		135,000		95,000
Readjustment of boundaries Zoological Park		60,000	....	
Total		883,580		419,580

RESEARCH.

It was a part of the original plan of the Institution that its Secretary should not give his time wholly to administrative duties, but should directly aid in its scientific investigations.[a]

Research work in various fields of science has been continued by the Institution and its dependencies.

I have made some progress toward the solution of the problem of mechanical flight, and have been carrying on, with the consent of the Regents, some experiments for the War Department, at its expense, and have added other experiments, partly at the expense of the Institution. Owing to an accident to the launching apparatus it was not possible to make a satisfactory test of the ærodrome, and the exhaustion of available funds has compelled the abandonment, at least temporarily, of the experiments.

In the Astrophysical Observatory I have continued work believed to be important, and inaugurated some experiments of novel interest, which are referred to later.

Through the Museum and the Bureau of American Ethnology the Institution has been enabled to carry on various biological, geological, and ethnological researches, which will be found fully described elsewhere in this report and need not be repeated here.

HODGKINS FUND.

Series of experiments conducted with the aid of grants from the Hodgkins fund of the Institution are still in progress. Among those sufficiently advanced to permit publication, the investigations of Dr. Carl Barus may be mentioned. Two memoirs detailing the earlier results of these experiments have already been issued in the Smithsonian Contributions to Knowledge, and a third report is now awaited, which will record experiments on the ionization and nucleation of air in contact with phosphorus and with water nuclei. Other interesting data in regard to the diffusion of vapor into nucleated air, periodic color distribution in coronas, etc., will be given in this memoir, which will probably be issued during the present year.

Dr. E. W. Scripture, of Yale University, to whom a grant was awarded for the construction of a "vowel organ," has been prosecuting his researches for the last year in Berlin. He reports numerous interesting experiments in the construction of resonators of various materials with which he has succeeded in producing the different vowel

[a] *Resolved*, That the Secretary continue his researches in physical science, and present such facts and principles as may be developed for publication in the Smithsonian contributions. (Adopted at meeting of the Board of Regents January 26, 1847.)

sounds. Doctor Scripture says the problem now before him is to replace the material used in the artificial glottis he has constructed, by a substance which can be more perfectly adapted to his purpose in some essentials than any he has hitherto availed himself of. When this object is attained, he expects to be able to construct an organ which can sing the vowels, or a vowel register which, attached to a pipe organ, may be effectively used in church music.

The memoir of Dr. Victor Schumann, of Leipzig, on the "Absorption and Emission of the Gases of Atmospheric Air in the Ultra-Violet Spectrum," mentioned in my last report as in course of publication, has now been issued in Volume XXIX of the Smithsonian Contributions to Knowledge. The special apparatus, devised and constructed by the author, is shown by plates in the memoir, and the method of using it described. Although Doctor Schumann considers this investigation but preliminary to further research in this region of the spectrum, specialists recognize that a notable step in advance has been made by the persevering and able work described in this memoir.

Photographs of the apparatus used by Prof. William Hallock in his Hodgkins research on the composition of vowel sounds, together with the curves drawn by the synthetic analyzer, have been submitted with a detailed description of the same. Although unexpected difficulties have been encountered in transferring the records to the magnetic wire, the investigation is reported as progressing, on the whole, satisfactorily, and sound records, secured by means of the complicated and ingenious apparatus made use of, are to be submitted.

A memoir summarizing the research of Dr. M. W. Travers, "On the Attainment of Very Low Temperatures," has now been issued as No. 1441 of the Smithsonian Miscellaneous Collections. The investigations of Doctor Travers, who has recently been appointed to the chair of chemistry in University College, Bristol, England, which have been temporarily suspended while awaiting the reconstruction of some parts of the apparatus essential to the investigation, are soon to be resumed, when further progress will be reported to the Institution.

Dr. R. von Lendenfeld, of the University of Prague, who was aided in 1900 by a grant from the Hodgkins fund for a study of the motion of birds in actual free flight, has recently submitted a paper on the structure of bird's wing feathers, written by Dr. E. Mascha, with the aid and under the supervision of Doctor von Lendenfeld. This paper, which treats of the morphology and physiology of flight feathers (*remiges*), studied microscopically, is of interest in connection with the Hodgkins research of Doctor von Lendenfeld, which I have mentioned in former reports.

The subscription of the Institution to the Journal of Terrestrial Magnetism and Atmospheric Electricity has been again continued, the copies thus secured being distributed, as before, to domestic and for-

eign libraries and establishments especially interested in the subjects treated of by the journal.

A grant has been approved on behalf of Dr. A. F. Zahm, professor of physical science in the Catholic University of America, in Washington City, for a series of experiments on the laws of atmospheric resistance to moving bodies. This research, which is still in progress, will be reported on later.

The experiments of Mr. Alexander Larsen, of Chicago, on lightning flashes and fluorescence, carried on by means of simple mechanism adapted and arranged by himself, have been aided by a moderate grant from the Hodgkins fund. These experiments, which are now in progress, are expected to yield results of scientific value.

In view of the numerous inquiries received from investigators and specialists, it may be again stated that the Hodgkins prize competition of the Institution was definitely closed December 31, 1894, and that no further competition on any subject is at present proposed by the Institution. A recent circular stating the conditions which, in accordance with the will of the donor, govern the administration of the Hodgkins fund, including also a mention of the Hodgkins medal, which may be awarded for important contributions to our knowledge of the nature and properties of atmospheric air, and stating the conditions governing the award of grants which are occasionally approved, is sent to those requesting it. A brief history of the Hodgkins foundation, noting the medals and prizes awarded, and mentioning the investigations which have been furthered by the fund, has been published in the Quarterly Issue of the Smithsonian Miscellaneous Collections.

NAPLES TABLE.

The question of the renewal of the lease of a table in the Naples Zoological Station, which was held under advisement for some months, was finally decided in the affirmative, and the contract renewed on behalf of the Institution for three years from January 1, 1904.

Since this action, applications for the seat have been received, and that of Prof. J. B. Johnston, head of the Department of Zoology in the University of West Virginia, which had been submitted a second time, in compliance with the rule of action observed in the interest of all candidates, was approved for six months from September 1, 1904. Doctor Johnston is the author of several important papers on the comparative anatomy of the brain and cranial nerves of the lower vertebrates, and his session will afford undoubted advantages for his study of the problems of vertebrate morphology and the evolution of the nervous system.

The additions to the buildings at the Naples Station now in progress will add much to the space available for research, and this, together with the larger number of tables now supported by scientific institu-

tions in the United States, will tend to obviate the not infrequent application by several students at the same time for the Smithsonian seat, a matter of regret, as in such a case some applicants must be disappointed, since an excess of workers at the same table is a source of inconvenience to Doctor Dohrn, the courteous director of the Station. It is, however, desired in the interest of science that the Smithsonian table should be continuously occupied during the months available for study at Naples, and all applications for the seat receive immediate consideration. A brief account of the administration of the Smithsonian table in the Naples Station, embodying the data which is likely to be of use to applicants, has recently been published in the Quarterly Issue of the Smithsonian Miscellaneous Collections.

It is a pleasure to state that the advisory committee remains unchanged, and to express thanks for the helpful attention given to all questions referred to the committee for consideration.

EXPLORATIONS.

The Institution has this year made explorations through its private funds, such as the Alaskan mammoth expedition, and that to the Canadian glaciers, mentioned below, in addition to the customary biological, geological, and ethnological ones through the National Museum and the Bureau of American Ethnology.

Alaskan mammoth expedition.—About the middle of May the Institution dispatched an expedition to Alaska under the direction of Mr. A. G. Maddren. The most important work sought to be accomplished is the collecting of remains of the mammoth and other large mammals, which have been reported as abundant in various regions, one place being known as the "Bone Yard," another as Elephant Point, along the south shore of Kotzebue Sound.

Exploration of Canadian glaciers.—An exploration of some of the glaciers of British Columbia has been undertaken by Dr. W. H. Sherzer, of Michigan, under the auspices of the Smithsonian Institution, for the purpose of gathering definite information regarding glacial phenomena, such as the nature and cause of the ice flow, the temperature of the ice at various depths, and its relation to air temperatures, the amount of surface melting, and the possible transference of material from the surface to lower portions. The special field of study will be the five most accessible glaciers along the line of the Canadian Pacific Railway, including the Victoria glacier at Lake Louise, the Wapta glacier in the Joho Valley, and the Asulkan, and Illecillewalt glaciers near Glacier House.

PUBLICATIONS.

The Institution distributed during the year a total of 45,705 volumes or parts of volumes of the series of Smithsonian Contributions,

Miscellaneous Collections, Reports and publications not included in the regular series.[a]

In the publications of the Institution the double aim of its founder is represented, in that it should exist both for the "increase" and the "diffusion" of knowledge.

The recording of results of original researches, the "increase" of knowledge, is chiefly through the Contribution to Knowledge, a quarto series begun in 1848, and in which 145 memoirs, collected in 33 volumes, have so far been published.

Three memoirs have been added to this series, one on the moon, one on reflecting telescopes, and one on whalebone whales.

The moon memoir, by Prof. N. S. Shaler, entitled "A Comparison of the Features of the Earth and Moon," is a work of 79 pages of text, with 25 full page illustrations, each of them accompanied by a description of the principal objects shown.

As stated in my last report, I have for more than twelve years past been preparing the material for the publication of a work, on the part of the Smithsonian Institution, which it was hoped would consist essentially of photographic views of the moon, so complete and, it was expected (with the advance of photography), so minute, that the features of our satellite might be studied in them by the geologists and the selenographer, nearly as well as by the astronomer at the telescope. This hope has only been partially fulfilled, for photography, which has made such eminent advances in the reproduction of nebulæ and like celestial features, has indeed progressed in lunar work, but not to the same extent as in other fields. The expectation that such a complete work could be advantageously published for this purpose has, then, been laid aside for the present.

It was decided to draw from the material prepared for this larger work, some photographs taken at the Lick Observatory and the Paris Observatory, and particularly some recently obtained by Professor Ritchey at the Yerkes Observatory, for which I have to express the thanks of the Institution. These illustrations are attached to the present paper by Professor Shaler, and may, then, be considered to be a separate contribution by the Institution to the study of selenography.

Professor Shaler's memoir gives the results of personal studies carried on for a third of a century. He has devoted about one hundred nights to telescopic study of the moon with the Mertz equatorial of Harvard College Observatory, his later researches having been chiefly by means of photographs at Harvard University, with which he has so long been connected.

A memoir of 106 pages, with 13 full-page illustrations and many text figures, consists of a reprint of a work by Professor Draper on

[a]Contributions to Knowledge, 3,148; Miscellaneous Collections, 7,819; Reports, 31,202; publications not in regular series, 3,536.

the construction of a silvered glass telescope, accompanied by a paper by Prof. G. W. Ritchey on the modern reflecting telescope and the making and testing of optical mirrors.

For few papers published by the institution has there been a more constant demand than for this memoir by Prof. Henry Draper, entitled "On the Construction of a Silvered Glass Telescope," originally issued forty years ago, in 1864. The paper is of remarkable merit as a summary of, and an addition to, the knowledge existing at the time, but during the long interval which has elapsed, progress has been made in various directions and by various hands. On the occasion of a new edition of this classic memoir, it was sought to give an account of the latest knowledge on the subject, and I was gratified to be able to obtain from Mr. Ritchey, whose labors in this direction are so well known, an account of the processes which he has employed for making the great mirrors that have been so effective at the Yerkes Observatory, and it has been decided to republish, with the original Draper memoir, but as an entirely independent contribution to the subject, the present article by Mr. Ritchey. The great refracting instruments which have been produced in recent years have not superseded the use of the reflector, which, on the contrary, is occupying a more and more important place. The reader is here presented with the most recent methods and results needed in the construction of great mirrors for modern reflecting telescopes.

The work on whales is by Dr. Frederick W. True, head curator of Biology in the National Museum, and treats in an exhaustive manner of the whalebone whales of the western North Atlantic compared with those occurring in European waters, with some observations on the species of the North Pacific. It makes a volume of 337 pages, with 50 full-page illustrations and 97 text figures.

Doctor True has here brought together extensive original data relative to the external and osteological characters of the large whales of the western North Atlantic, for the purpose of determining whether the species are the same on both sides of that ocean. The facts have been derived from a study of fresh specimens at the Newfoundland whaling stations, the collection of the United States National Museum, and the skeletons in other large museums of the United States. Special study was given to the type specimens of American species proposed by Prof. E. D. Cope and Capt. C. M. Scammon, all of which, with one exception, were examined by the author.

The investigation is preparatory to a study of the geographical distribution and migrations of the larger cetaceans in the North Atlantic, which could not be undertaken until the identity of the species themselves was determined. Numerous facts, however, relating to the occurrence of whales at different points off the coasts of North America and the seasons of their appearance and disappearance, have

been assembled. The results of the investigation show that several American species which have been proposed are quite certainly nominal, and that, as a whole, the species of the Atlantic coast of North America can not be distinguished from those of European waters. Some attention has been paid to the whales of the North Pacific. The information previously recorded has been brought together in orderly sequence and various new facts added, but the amount of material at present available is insufficient to serve as a basis for discrimination of closely allied species. It is certain, however, that the whales of the North Pacific, with one exception, bear an extremely close resemblance to those of the North Atlantic. The California Gray whale, *Rhachianectes glaucus*, has no counterpart in the Atlantic. One well known European species, the Pollack whale, *Balænoptera borealis*, not previously known in North American waters, was observed at the Newfoundland whaling stations while this volume was passing through the press. The illustrations include views of the type specimens of the species proposed by Cope and Scammon; also numerous representations of the different individuals of the Common Finback and the Sulphurbottom, from photographs taken by the author at the Newfoundland whaling stations. The latter are of special value for the study of individual variation in these huge animals.

The series of Smithsonian Miscellaneous Collections is intended to include all the publications issued directly by the Smithsonian Institution in octavo form, excepting the Annual Report, which is a Congressional document. In the Collections are included reports on the present state of our knowledge of particular branches of science; instructions for collecting and digesting facts and materials for research; lists and synopses of species of the organic and inorganic world; Museum catalogues; reports of explorations; aids to bibliographical investigations, etc., generally prepared at the express request of the Institution and at its expense.

A NEW QUARTERLY ISSUE.

Since 1862, when the series of Miscellaneous Collections was begun, there have been published 45 volumes, made up of several hundred individual papers.

In order to afford a medium for the early publication of the results of researches conducted by the Smithsonian Institution and its bureaus, and especially for the publication of reports of a preliminary nature, I have decided during the past year to establish a quarterly issue of the Miscellaneous Collections, which shall not supersede the regular series, but be a part of it. Each number of the quarterly is planned to consist of about 144 pages of text and to be suitably illustrated. The first volume has been completed, and makes a book of 463 pages.

including 28 papers, with 103 plates and 45 text figures, as enumerated by the editor in the appendix to this report.

To the regular series of Miscellaneous Collections the following papers have been added:

The Literature of Thorium, by Dr. Cavalier H. Joüet; Phylogeny of Fusus and its Allies, by Prof. A. W. Grabau; Researches on the Attainment of Very Low Temperatures, by Prof. Morris W. Travers, and a Select Bibliography of Chemistry (Second Supplement), by Dr. H. C. Bolton.[a]

There was in press at the close of the year a Catalogue of Diptera, by Prof. J. M. Aldrich, and Researches in Helminthology and Parasitology, by Dr. Joseph Leidy.

The Smithsonian Report is printed as a Congressional document and is its only publication of which the edition is large enough to permit even a limited distribution to individuals. In the general appendix to the report it has been my especial aim to include, as heretofore, papers of scientific importance, treated in a way to be understood by the lay student. The Report for 1903 has been put in type, but had not been delivered by the printer at the close of the fiscal year. The volume contains the Secretary's report to the Regents for the year ending June 30, 1903, the proceedings of the Regents' meeting of January 28, 1903, and the report of the Executive Committee dated January 25, 1904, besides the general appendix of about 50 papers on scientific subjects relating chiefly to the calendar year 1903.

Among the many manuscripts left unfinished by the late Dr. G. Brown Goode, there is a group of chapters dealing with the progress of science in America. In accordance with the author's liberal interpretation of the meaning of science, the work does not confine itself to the physical and natural sciences, but contains notes on anthropology, philology, bibliography, and kindred subjects. As Doctor Goode was eminently the historian of American science, it seems especially fitting that the Smithsonian Institution should undertake the publication of these memoirs, even if incomplete. The manuscript is now being worked over and I hope that in the near future these notes will in book form serve as a foundation for and a stimulus to further work in the same direction.

LIBRARY.

The accessions to the Smithsonian deposit in the Library of Congress during the year aggregated 2,286 volumes, 21,467 parts of volumes and pamphlets, and 215 charts, making a total of 23,968 catalogue entries, equivalent to nearly 15,000 octavo volumes. Additions

[a] Dr. Henry Carrington Bolton died on November 19, 1903, before the publication of this work.

aggregating 7,893 entries have been made to the libraries of the Secretary, Office, Astrophysical Observatory, the National Zoological Park, and the National Museum. In the Museum library there are now 20,548 bound volumes and 35,950 unbound papers.

General de Peyster continues to add many valuable volumes to the Watts de Peyster Collection Napoléon Buonaparte, and there have also been received from him several oil paintings, and many historical relics of the American colonial period.

International Catalogue of Scientific Literature.—The Institution has continued the work of indexing scientific publications, the total number of references sent to the central bureau at London during the year aggregating 21,213, or an increase of 50 per cent over the previous year, which was made possible by an addition to the allotment from the Smithsonian fund for this work. The first annual issue of the catalogue has now been published and distributed, and also several volumes of the second annual issue.

CORRESPONDENCE.

As in former years, a great many inquiries on almost every known subject have been received by the Institution, and although many of these did not relate directly to its operations, it has, in accordance with the purpose of its foundation—"the increase and diffusion of knowledge"—cheerfully furnished the information, as far as practicable, in each case, notwithstanding the fact that this frequently required the expenditure of considerable time by the members of its staff.

All correspondence in any way affecting the policy of the Institution or its bureaus has, as heretofore, received the Secretary's personal attention, while letters relating to the work of the National Museum, the Bureau of American Ethnology, and the National Zoological Park, not included in the above class, have been acted on directly by the Assistant Secretary in charge of the Museum, the Chief of the Bureau, and the Superintendent of the park.

During the year many plans and descriptions of devices of various kinds have been submitted to the Institution for an expression of opinion as to their merits. These requests the Secretary has been compelled to decline by reason of the decision of the Board of Regents, made during the early years of the Institution, which prohibits him from expressing an opinion upon the merits of any patentable invention.

No important changes have been made in the system of conducting correspondence, which was inaugurated in 1890, and which has continued to be found an effective means of preventing any unnecessary delay in its dispatch.

INTERNATIONAL AMERICAN ARCHÆOLOGICAL COMMISSION.

At the Second International Conference of the American Republics, held in the City of Mexico on January 29, 1902, a resolution was adopted recommending that an—

"International American Archæological Commission be formed through the appointment by the President of each of the American Republics of one or more members of such commission; * * * that the first meeting for the organization of the commission, the election of officers, and adoption of rules shall occur in the city of Washington * * * within two years from this date; that the commission shall have power to appoint subcommissions, which shall be charged specially with the explorations or other work committed to its care; that subcommissions may be appointed which shall cause the cleaning and preservation of the ruins of the principal prehistoric cities, establishing at each of them a museum to contain objects of interest found in the locality, and, at such exhumed cities, to establish conveniences for the visiting public; that the commission endeavor to establish an American International Museum which is to become the center of all the investigations and interpretations, and that it be established in the city selected by the majority of the Republics acquiescing in this recommendation." * * *

The attention of the Smithsonian Institution was called to this proposed commission through a letter from the secretary of the conference, dated May 26, 1902, asking for suggestions as to the best methods to be pursued to bring about the early establishment of the commission and its effective organization.

A preliminary meeting of representatives appointed by some of the Republics to consider the proposed commission was held at the Department of State on April 15, 1903, and adjourned to the third Monday of December.

On May 15, 1903, the Secretary of State submitted to me for consideration, and an expression of views thereon, a proposed plan of organization of the commission.

On December 21, 1903, a meeting of the diplomatic representatives of the American Republics was held at the Department of State in the interest of the organization of the International Archæological Commission, when representatives of the Smithsonian Institution were invited to state to those present the position of the Institution in regard to the work of the proposed commission, and to submit such views in writing, to be printed in the proceedings of the meeting, for the information of the several Republics, and adjournment was had until the third Monday in December, 1904.

On February 16, 1904, in response to a request from the Secretary of State, the following letter was submitted:

SMITHSONIAN INSTITUTION,
Washington, U. S. A., February 16, 1904.

SIR: In reply to the communication of the Department of the 8th instant, requesting the presentation of "the formal views and constructive criticisms of the Smith-

sonian Institution on the project of the International Archæological Commission submitted to the diplomatic representatives of the American Republics," I have the honor to say that no copy of the proceedings of that meeting has been laid before me. I understand that a project was submitted at a previous meeting, and that practically no action was taken at the last meeting alluded to. I have, in accordance with the request of the Department, caused the accompanying memorandum to be prepared. I beg at the same time to refer you to my previous letter to the Department, of December 12.

I am, etc.,

S. P. LANGLEY, *Secretary*.

Hon. JOHN HAY,
Secretary of State, Washington.

[Inclosure.]

MEMORANDUM CONCERNING THE PROPOSED COOPERATION AMONG THE AMERICAN REPUBLICS FOR THE PROMOTION OF ARCHÆOLOGICAL AND ETHNOLOGICAL RESEARCH.

The Smithsonian Institution strongly favors international cooperation in the furthering of scientific work. It initiated and is at present engaged in the international exchange of scientific publications, having agencies throughout the world, besides acting on behalf of the United States Government for the exchange of public documents. It is also acting as the representative of the United States in the compilation of the International Catalogue of Scientific Literature.

There is especial force in such cooperation among the American Republics for the promotion of archæological and ethnological research, and, for that matter, among all the countries upon the American continent and the adjacent islands, since the problems, so far as they relate to the aboriginal populations, are not defined by present political boundaries. British, Dutch, French, or other foreign possessions on the American continent or in the West Indies could with advantage be included in the project.

This cooperation can be best furthered in the first instance by the stimulation of the organizations already in existence for these studies in the various countries. The work is in almost all of the American countries carried on at present by the national museums. In the United States it is carried on by the National Museum and the Bureau of American Ethnology. Wherever such exist it is desirable that they should have the opportunity of an exchange of views and the comparison of work to be undertaken in order that the great problem, which can only be solved by coordination of research, shall be taken up with the greatest efficiency and economy. An organization of the heads of museums and scientific government bureaus having to do with archæology or ethnology could be effected through the Bureau of American Republics, an existing organization.

To further stimulate archæological work each American Republic or other State willing to adhere to the scheme might undertake to secure the passage of laws declaring archæological and historical objects of unusual interest reserved, and that excavations thereon should be undertaken only by properly organized museums and all waste of archæological objects should be prevented.

The director of the national museum in each country, the head of a bureau or department devoted to the study of archæology and ethnology, or, where there are none such, some other official duly appointed, should, in executing the law for the protection of antiquities, have a recording officer who should secure a list of all objects taken from the ground.

The passage of laws prohibiting the manufacture of spurious antiquities is also desirable. Such laws, being national laws, would necessarily be executed by national authorities, and each republic or other country or province would be autonomous in this respect.

An archæological survey of America, undertaken by the various States systematically, and upon a well-defined plan, would render an important service to the progress of archæological science, and is a preliminary to systematic research.

Whenever a museum or scientific establishment exists now undertaking archæological and ethnological work this should remain the representation of the specific country for such work. The interchange of duplicates among American museums, which is already being carried on to a considerable extent, should be continued and increased, in order that each American national museum should finally have as good a series as is obtainable of all American archælogical objects of interest. Care should be taken, however, not to let this idea interfere in the proper exchange of specimens between museums on this continent and elsewhere, since most museums, while supported by nations, are really international in character, and it is to the interest of American museums that they shall exchange American material for foreign material, as it is to the interest of foreign museums that they shall have material representing American archæology. It is only by securing archæological and ethnological series from all countries that comparative studies can be successfully entered upon.

While uniformity is not sought, the American museums should exchange with each other plans of cases, information with regard to methods of installation and kinds of labels, and regulations concerning the preservation of type specimens, and the lending of specimens from one museum to the other for study or other purposes, in order that each national museum may have all methods before it to assist in adopting such as are best suited to its own peculiar needs.

The existence of a unique object, manuscript, or codex, without its reproduction by cast, photograph, or other mechanical means, renders it possible in the event of fire or other disaster that all the knowledge represented by these objects will be lost to the world. The copying by mechanical means of such specimens and their exchange among the various countries is suggested as one of the most important pieces of work that could be undertaken by international cooperation.

The projects originally presented to the conference of the American Republics at the City of Mexico, in so far as these are practicable, can best be carried out in the following manner: That the directors of the national museums of the American Republics and States, or, in case where there be none, then other representatives of these countries, be constituted as a body, with wholly advisory functions, to meet once every three years, or oftener should occasion arise, to consider archæological and ethnological interests. The meetings and deliberations of this body should be conducted under the auspices of the Bureau of American Republics, which might publish such reports as might be approved by a proper committee of the meeting. The organization here suggested to carry out the purposes of the project could be effected with slight expense to the States adhering to the plan.

INTERNATIONAL CONGRESSES AND EXPOSITIONS.

The Institution was called upon during the year to designate delegates to an unusual number of international scientific congresses, and several more were under consideration at the close of the fiscal year.

Congress of Americanists.—Mr. William H. Holmes, Chief of the Bureau of American Ethnology, was appointed delegate of the Institution to the Fourteenth International Congress of Americanists to be held at Stuttgart, August 18–23, 1904, and upon nomination by the Institution the following persons were accredited by the Department of State as United States delegates to the same congress: Dr. Franz

Boas, of the American Museum of Natural History; Mr. Marshall H. Saville, of the Columbia University; Dr. George H. Dorsey, of the Field Columbian Museum, and Doctor Currier, of the Catholic University of America.

Congress of Zoology. Messrs. Leonhard Stejneger and Gerrit S. Miller, jr., of the United States National Museum, were appointed representatives of the Institution and the Museum at the Sixth International Congress on Zoology, to be held at Berne, Switzerland, August 14–19.

Congress of Education.—Dr. Cyrus Adler was appointed delegate of the Smithsonian Institution to the International Congress of Education, held in St. Louis June 28 to July 1, 1904, but finding it impossible to attend he was represented by Dr. Marcus W. Lyon, jr., of the National Museum.

Congress of Orientalists.—Prof. Paul Haupt, honorary curator of the Division of Historic Archeology in the United States National Museum, was appointed representative of the Smithsonian Institution and the National Museum at the Fourteenth International Congress of Orientalists, to be held at Algiers in April, 1905.

Congress of Geology.—Mr. Charles Schuchert, of the National Museum, was appointed delegate of the Institution to the Ninth International Geological Congress held at Vienna, August 20–29 1903. He reports that there were 355 members in attendance, including 22 from the United States. The standard of the papers presented was high. One day was occupied by 7 speakers from various parts of the world in presenting a synopsis of present knowledge of crystalline rocks. Another day was devoted to "Faults and Clefts," and a third day was given to a presentation of the geology of the Balkan Peninsula and the Orient.

Archæological Congress.—Dr. Franz Boas was appointed United States delegate to the Congress of the Archæological and Historical Federation of Belgium, to be held at Mons in July and August, 1904.

Louisiana Purchase Exposition.—By an act of Congress approved March 3, 1901, liberal provision was made for an exhibit at the Louisiana Purchase Exposition by the Executive Departments, the Smithsonian Institution, the National Museum, the Fish Commission, and the Department of Labor, "of such articles and objects as illustrate the functions and administrative faculty of the Government in time of peace and its resources as a war power, tending to demonstrate the nature of our institutions and their adaptation to the wants of the people." The preparation of this exhibit was placed in charge of a Government board upon which Dr. Frederick W. True, head curator of the department of biology in the National Museum, was appointed as representative of the Smithsonian Institution. The exposition was

postponed from 1903 to 1904, and opportunity was thus offered for the preparation of an adequate display that might illustrate the functions of the Institution and its dependencies.

The Smithsonian exhibit proper is installed in the Government building in a pavilion which overlooks the space assigned to its various bureaus. It contains memorials and a portrait of the founder, James Smithson, and a complete series of the several hundred publications of the Institution, which represents one of the chief means adopted for carrying out his purpose "The increase and diffusion of knowledge." Portraits of the chancellors and secretaries of the Institution are also shown, as well as that of Mr. Thomas George Hodgkins, the donor of the Hodgkins fund. Printed matter, setting forth the objects to which this fund is devoted and the reports of important original researches which it has aided by means of grants, are also exhibited, with reproductions of the Hodgkins gold medal, which is awarded biennially for noteworthy investigations regarding the nature of atmospheric air in connection with the welfare of man. One of the features of the exhibit is a quarter-size model of the large aerodrome with which experiments were conducted during the summer and autumn of 1903, a model, driven by a gasoline engine, which itself has flown a distance of nearly a quarter of a mile. The steam-driven model with which experiments were successfully made in 1896 is also exhibited.

The work of the Astrophysical Observatory is illustrated in a graphic manner by the installation of the great coelostat, arranged to throw a beam of sunlight into a darkened room where there is shown a solar image about a yard in diameter, thrown up by a 6-inch telescope, and the solar spectrum is formed upon the walls by a large concave grating. Bolometric apparatus is in actual operation, while a display of transparencies illustrates the apparatus and results of researches by the Observatory.

Charts and other objects are displayed explanatory of the useful work carried on by the International Exchanges in distributing scientific publications throughout the world.

The various departments of the National Museum are fully represented. Among some of the objects displayed I may mention a restoration of the extinct reptile known as the Stegasaur, about 25 feet long, which is not unlike a large horned toad, with a double row of large, flat spines along the tail; a collection of meteorites and casts of some of the largest meteorites known, one of them exceeding 20 feet in length and weighing many tons; a collection of some of the most beautiful kinds of minerals from all parts of the world; the model of a whale 80 feet long as showing the appearance of the greatest of all living animals; groups of game birds, the wonderful birds of paradise, the gorgeous pheasants, and birds of prey; and a remarkably perfect

egg of the gigantic bird of Madagascar, the Aepyornis, the egg measuring about a foot long.

The Children's Room in the Institution is reproduced in full size, together with its cases, aquaria, bird cages, decorations, and as many of the objects as could be duplicated. There is thus shown a lilliputian museum which has proved very attractive to the older as well as younger visitors to the Exposition.

A gigantic bird cage, in which many species of birds have almost as much freedom of movement as if they were without restraint by bars and nets, illustrates the National Zoological Park.

The collections are mentioned with somewhat more detail in the Appendix, and in the report by Doctor True, to be published later in another volume, full details will be given of these exhibits as well as descriptions of some great models of Mayan temples of Yucatan, shown by the Bureau of American Ethnology.

Lewis and Clark Exposition.—Congress during the past year made provision for a Government exhibit at an exposition to be opened at Portland, Oreg., in May, 1905, to commemorate the centennial of the Lewis and Clark Expedition to the Northwest, and Dr. F. W. True has been designated as representative of the Institution to prepare a suitable Smithsonian exhibit.

MISCELLANEOUS.

University of Wisconsin.—Dr. James B. Angell, president of the University of Michigan and Regent of the Smithsonian Institution, represented the Institution at the celebration of the fiftieth anniversary of the first commencement of the University of Wisconsin, held at Madison during the week beginning June 5, 1904, and presented the congratulations, signed by the Secretary, in the following form:

> The Smithsonian Institution extends to the president, the regents, and the faculty of the University of Wisconsin its congratulations on the occasion of the fiftieth anniversary of the first commencement of the university. It felicitates the university on the important work accomplished by it for learning and education in the State of Wisconsin, and, recognizing its influence also in sister institutions of learning, sends heartiest wishes for its continued prosperity and usefulness.

NATIONAL MUSEUM.

The most notable event of the year was that on June 15, 1904, ground was broken for the new Museum building which was authorized by act of Congress approved March 3, 1903, the first sod being turned by me in the presence of the architects, the superintendent of construction, and the officers and employees of the Institution and its dependencies. The new structure will be erected on the northern side of the Smithsonian Park and will be about 551 feet long

and 318 feet wide, giving a floor area of about $9\frac{1}{2}$ acres in its four stories.

The year which sees this most important material accession has been one in which the Museum's most important possession, in the men of science who have devoted themselves to its work with a disinterested zeal, has suffered a loss in the resignation of a number of its staff, from the lack of appreciation by Congress which would permit it to retain their services. The time in the Museum's history has come, anticipated in my previous reports, when the staff so slowly gathered, and which is to occupy this new building, is beginning to decline. I feel compelled here at the outset to call attention to the inadequate salaries paid to the scientific and clerical staff of the Museum, a circumstance that during the past year has caused the resignation of several of the curators, who have accepted similar positions offering greater compensation in other cities. An increase in the Museum appropriation has been asked of Congress, since under the present appropriation it is impossible to maintain a proper staff of efficient scientific assistants or clerical help.

Good progress has been made in the regular operations of the Museum, although much time of the scientific staff has been devoted to the preparation of exhibits for the Louisiana Purchase Exposition.

The new accessions aggregated 241,547 specimens, making the present total census of collections 5,891,000 objects. Important new accessions in the anthropological, biological, and geological departments are enumerated by the Assistant Secretary in the appendix to this report.

I may mention here the continued interest in the National Collections manifested by Dr. W. L. Abbott, who each year presents to the Museum many objects collected by him during his anthropological and natural history researches in the Far East, the specimens received during the last year consisting chiefly of ethnological objects from the Malay Peninsula and northern Sumatra. Ethnological specimens collected in the Philippine Islands by Drs. E. A. Mearns and R. B. Grubb, of the United States Army, and objects of interest collected in Alaska by Lieut. G. T. Emmons, of the United States Navy, evidence the present interest of many Government officials in the work of the National Museum. The Bureau of Ordnance of the War Department has deposited 615 varieties of firearms of historical value.

The National Museum acquires its collections mainly through Government surveys, by gift and by exchange, but, depending upon these means alone, its collections can never be made complete in any particular. Provision should be made for filling at least the more important gaps by purchase. The objects to be obtained in this manner are generally such as find their way into the hands of individuals who have been at greater or less expense in obtaining them, and who,

therefore, can not be expected to part with them except by sale. About four years ago a specific item for purchase was agreed to by Congress, and while the sum allowed was altogether inadequate to meet the requirements of the Museum, yet through it many important objects were secured. In the appropriation bill for the past year this item was omitted by Congress, and many objects which should have come into the possession of the Government have been obtained by other museums. This is especially the case in connection with the Louisiana Purchase Exposition, where exceptional opportunities were presented for enriching the National Collections with needed material.

When the Museum building was erected, the need of a working library actually at hand was felt, and through the generosity of Professor Baird, who presented his entire private collection of scientific publications to the National Museum, the nucleus for such a library was established. In the years following, the Library of Congress became so overcrowded that it was glad to have retained at the Museum as much of the Smithsonian Library as was useful, and to send down for indefinite deposit as many of the Smithsonian books as were required. This condition no longer obtains, however, and an enlarged working library for the Museum has become absolutely essential, if the provisions of Congressional enactments for the classification and arrangement of its collections are to be carried into effect. The sums of money heretofore available have not sufficed even for the purchase of all such books needed in the work as were not contained in the collection of the Library of Congress or in the Smithsonian deposit, and the increase requested is a low estimate for the actual requirements of the Museum.

The National Museum is open to the public only on week days, from 9 a. m. to 4.30 p. m., and its important educational features are restricted to persons having leisure only during official hours. It has long been urged that means be granted for so extending the hours of opening that no one shall be deprived of the advantages which it offers for instruction and enlightenment. Such an arrangement has been in successful operation at the Library of Congress for several years, and a similar course has long been followed by the larger museums elsewhere in this country and in most European capitals. The National Museum has recently been provided with a complete installation of electric wires and lamps, and could, therefore, be opened both evenings and Sundays at the mere cost of the necessary additional supplies and help. The Smithsonian building, however, has not yet been furnished with the means for lighting the public halls, but could be opened on Sundays. The expense involved is that needed for obtaining the extra amount of coal and of electric current required, and for the employment of a few additional persons to supplement the night and Sunday watch force,

which is very small. Three plans are suggested for the extension of the hours of opening. The first includes every week-day evening and Sundays; the second, three evenings during each week and every Sunday; the third, Sundays only. The first plan most strongly commends itself.

The progress of the work of classifying and arranging the collections both for exhibition and for study has been greatly retarded, as during many years past, by lack of space and by reason of the insufficient force provided. The difficulty in regard to space will cease with the completion of the new building authorized by Congress in 1903, but that completion is still years distant. I can not too strongly urge that when the building is ready an adequate staff of scientific men can not be improvised, but that such an one must be largely gathered in the time which now offers for preparation if one is to be provided adequate to the demand.

BUREAU OF AMERICAN ETHNOLOGY.

The past year's work of the Bureau has continued mainly along the usual lines, and in a number of directions is making rapid progress toward final results.

The research work among the aborigines has been carried forward in four widely distributed regions—among the Haida tribes of the Queen Charlotte Islands and southern Alaska; among the Pueblo Indians of New Mexico; among a number of tribes of the great plains in Oklahoma and Indian Territory, and in the West Indies where the interesting and obscure problems of the ancient remains and tribal remnants are receiving deserved attention. The studies in these several fields are now gradually approaching completion, and monographs embodying the results are in hand.

In the field of linguistics much attention has been given to the collection of data from the tribes and the preparation of a handbook of the American languages, which is expected to mark a very decided advance in the knowledge of primitive tongues.

An important feature of the year's work was the preparation and installation of an exhibit intended to illustrate at the Louisiana Purchase Exposition certain phases of the Bureau's work, and special studies were pursued and collections made for this purpose.

A measure for the preservation of our national antiquities was introduced in the Senate by Senator Cullom, and a similar measure was offered in the House of Representatives by Mr. Hitt. Since other legislation along the same lines has been proposed to Congress and the subject is still under discussion, no final action having been taken, it is not desired to say more here than that the Institution, through the Bureau of American Ethnology, is deeply interested in the proposed

plan for preserving the antiquities of our country and awaits the commands of Congress in the matter.

I have continued to take much interest in the preparation of the Dictionary of Indian Tribes, not only for its value as a scientific memoir, but especially for its hoped-for utility in bringing before Congress the past, present, and future work of the Bureau. I stated in my last year's report that the work contemplates the publication of two octavo volumes, embodying in compact form information gathered by the Bureau during the past years regarding American races, the first of which volumes, it was then believed, would be ready for the press at the close of the year. The distribution of this important work has been delayed beyond the time anticipated, owing to the desire of those engaged in it to have it represent the latest views of ethnologists on the subjects treated, as well as a history of the past work of the Bureau, and to the fact that the means at disposal have not permitted that provision of skilled assistants which would have enabled the work to be completed at the time at first confidently expected. It is now believed that the first volume of the dictionary will be ready for the printer before the appearance of the present report, though it may yet be some time before it is received from the press, owing to the time actually required for the printing of the volume.

The printing of the annual reports and bulletins, including various scientific papers, is progressing favorably, and matter for the Twenty-fourth Annual volume, that for 1904, is practically ready for the press.

It is believed that important results would be derived from a study of the languages, manners, and customs of the natives of Hawaii and Tutuila, and Congress has been asked to approve the extension of the activities of the Bureau to these islands.

INTERNATIONAL EXCHANGES.

The International Exchange Service has for many years been the medium of exchanging the official publications of the United States Government with those of foreign countries and a like interchange of the publications of the Smithsonian Institution and of the principal scientific societies of this country with those of scientific bodies throughout the world. A new exchange list of foreign institutions was published during the year numbering 12,720 addresses, an increase of 3,306 addresses of such institutions since the publication of the last list in 1897. The total number of foreign and domestic correspondents is now 48,072, an increase of 4,060 correspondents during the past year. Of this number 16,721 are classed as institutions and 31,351 as individuals, the United States patrons of the service including 3,464 institutions and 6,450 individuals. The operations of the service during the last fiscal year show a gain of 8,766 in the number of packages

handled, the total for the year being 158,983, having an aggregate weight of 481,410 pounds.

The chief clerk of the service, Mr. W. Irving Adams, visited Europe during the year and was successful in promoting a more general interest in the interchange of books with several countries, as well as inaugurating many improvements in the prompt transmission of packages.

Dr. Carl Felix Alfred Flügel, who had served as agent of the Institution at Leipzig for forty-nine years, died on February 6, 1904, and was succeeded by Mr. Karl W. Hiersemann, of the same city.

Some progress has been made toward the reestablishment of exchange relations with China, and in general the condition of the "Exchanges" is one to cause satisfaction to those who are laboring for its advance.

NATIONAL ZOOLOGICAL PARK.

Under the care of the Regents the National Zoological Park continues to fulfill the objects of Congress in its foundation so effectively that perhaps no department of the Government service gives such widespread benefit in health and pleasure to the inhabitants of the District. As a consequence the number of visitors constantly continues to increase, there having been considerably more than a million during the past year.

The number of animals exhibited and maintained in the park has gradually augmented year by year, the net increase during the past season amounting to more than 10 per cent of the total on hand at the beginning of that period. This has necessarily occasioned a crowding, which is not conducive to the welfare of the animals. In order to relieve this in some degree, it was decided to build a new house which should serve as quarters for some of the more important ones and in which they would be under more wholesome conditions of temperature. This house will be a substantial stone structure, not unduly conspicuous, but harmonizing with the group in which it stands. At the present time only the walls of this building are completed. The cost of construction will be defrayed from the general appropriation for the park, which necessarily prevents any considerable expenditure of funds for other objects than the maintenance and care of the collection. A plan of the building is given in the superintendent's report (Appendix IV).

I have in previous reports during the past ten years urged the desirability—even the imperative necessity—of provision for the preservation of our vanishing races of animals, if they were to be saved from extinction. Repeated experience has demonstrated the fact that some of the largest of our native herbivorous animals will not thrive when closely confined. Even the American bison, it appears, can not

long be successfully bred except where given extended range. Herds kept on restricted areas may do well for a time, but eventually their vitality becomes impaired, the birth rate diminishes, and it is only by the addition of new animals bred in comparative freedom that the continued propagation of the species under such conditions can be secured. The recommendations made to Congress in previous years for the establishment of preserves and other measures to insure the continued existence of some of these notable animals have not secured favorable action. I fear that already this matter is passing beyond control, for no power can recall a vanished race.

The varied topography of the park, presenting as it does a succession of valleys and hillsides of unusual beauty, makes it eminently adapted to such treatment as would protect indigenous flowers and trees and maintain them in the best conditions attainable. What is known to landscape gardeners as a "wild garden"—that is to say, a plantation of indigenous plants allowed to grow with freedom, yet arranged so as to produce unobtrusive artistic effects—can be applied to many portions of the park with excellent results. Something of this kind will probably be attempted on a small scale should the appropriation permit. All such attempts, however, should and will be made subordinate to the prime object of the park, namely, that of maintaining a zoological collection.

The policy of encouraging wild animals and birds to make the park their home has been increasingly followed, and were it practicable to employ sufficient force to thoroughly police the park and its entrances, herds of Virgina deer and perhaps of the American antelope might be allowed to run free within it. The principal difficulty experienced in caring for animals and birds thus running wild lies in their tendency to stray away and get into the more extensive woods in the Rock Creek Park or its neighborhood, where they are often killed. It would be an advantage if the killing of game animals could be absolutely prohibited in the District of Columbia, for if such prohibition were made it would be possible within a few years to have a considerable collection of animals and birds living in perfectly natural conditions and with but little fear of man. I shall gladly aid in procuring any legislation to this end.

In order to bring to the notice of the general public the aims and objects of the National Zoological Park, it was thought desirable to make at the Louisiana Purchase Exposition a more significant exhibit than has heretofore been shown. Accordingly application was made for a large "flying-cage" in which to exhibit birds in conditions as nearly natural as possible. The United States Government Board considered the matter favorably, and an exhibit of this character was accordingly installed, and at the close of the year was in successful operation. I

have been pleased to learn that no part of the Government exhibits has excited more popular interest there.

Congress at its last session took up the important question of the definitive arrangement of streets in the vicinity of the Zoological Park, and established, by law, two such thoroughfares, one on the southeastern, the other on the western side of the park. Two comparatively narrow strips are thus left between these roads and the park boundary, and it would be of great advantage if these strips could be added to the park. Attention has been called to this matter in previous reports, and I have again submitted to Congress an estimate of the sum required to effect the necessary purchase.

I can, in conclusion, repeat my statement that the park is fulfilling more amply than ever the objects for which Congress founded it, "the advancement of science and the instruction and recreation of the people."

ASTROPHYSICAL OBSERVATORY.

In my last year's report I stated that it was probable that the radiation of the sun after absorption by the earth's atmosphere as received at Washington, appeared to have fallen off by 10 per cent, and I added that there had possibly been a decrease of the solar radiation itself since the early part of the year 1903. I observed in this connection that there seemed renewed promise of progress toward the foretelling by such means of the remoter changes of weather which affect harvests, which was one of the great aims had in view in the foundation of the observatory.

With the aid of the large horizontal telescope and the apparatus for obtaining distinct vision introduced by me and described in my last report, and more fully in that for the present year, I have continued these investigations, particularly with reference to the increase or diminution of the original solar radiation, apart from that absorbed by the earth's atmosphere, and by means which are unaffected by that absorption. These observations, independent of any theory upon the subject, indicated that at the time of the observation in the last report this radiation fell off at the source of energy in the sun, and that changes in the transmissibility of the solar atmosphere were a possible cause of at least a part of the effect observed on the earth. The amount by which this solar radiation was diminished, as determined at the source in the sun itself, appears to be in general accord with the statements of meteorological observatories as to the changed temperature at the earth's surface. I do not, however, venture to make the statement that the diminution was unquestionably due to a change in the solar envelope as an established fact, until further observations have been made, while I still call attention to the high importance of additional study of the question.

NECROLOGY.

DR. CARL ALFRED FELIX FLÜGEL.

In the death of Doctor Flügel, which occurred in Leipzig, February 6, 1904, the Smithsonian Institution lost a loyal assistant and an intelligent and capable representative. Doctor Flügel was appointed agent of the International Exchange Service of the Institution for Germany, Austria, and the adjacent countries in 1855, a position he filled for the remaining nearly fifty years of his life. He was the official successor of his father, Dr. Johann Gottfried Flügel, who was made agent of the Smithsonian Exchange Service, at the time of its organization in 1847, by Prof. Joseph Henry, first Secretary of the Institution, he also having filled the position until his death in 1854. The son succeeded his father as United States vice-consul in Leipzig also, this position under the Government proving likewise a life appointment in the case of both father and son.

Dr. Felix Flügel was scholarly in his tastes and occupations by both inheritance and training, the father having been the first lecturer in English in the University of Leipzig, where he received his doctor's degree in 1824, publishing in the same year a Grammar of the English Language, which remains a noteworthy record of the earlier period of English philology in Germany. Both father and son were persevering and laborious students in English, each publishing pamphlets and critical essays on the language, and each being the author of an English and German dictionary, that of the son having become a standard work, which reached its fifteenth edition in 1891.

The long tenure of office of Dr. Felix Flügel gave him an exceptional opportunity to further the exchange work of the Smithsonian Institution throughout central Europe, and believing that the system was an important medium of scientific intercourse between the United States and Europe, he labored untiringly for its development along practical lines, at the same time adding to exact business methods the charm of a personal courtesy and kindness which won many friends.

It would be difficult to overestimate the intelligent and faithful service rendered to the Institution for so many years by Doctor Flügel, and the appreciation of his character expressed by those officials whose fortune it was to know him personally is a sincere tribute to his capability and worth.

DR. HENRY CARRINGTON BOLTON.

Doctor Bolton, who died on November 19, 1903, was an earnest worker in the field of chemical bibliography. He unselfishly devoted many years of patient personal toil to the preparation of reference books of much value to all interested in the study of chemistry. He also

compiled a catalogue of scientific periodicals of the world. Many of the results of his labors were by him freely presented to the Smithsonian Institution and were published in the series of Miscellaneous Collections.

Doctor Bolton was born in New York City January 28, 1843. He graduated from Columbia College in 1862, and during the next four years studied at Heidelberg and Berlin, in 1866 receiving the degree of Ph. D. at Göttingen. In 1875 he was assistant in the laboratory of the Columbia School of Mines, in 1875 professor of chemistry at the Woman's College of the New York Infirmary, from 1877 to 1887 professor of chemistry at Trinity College, Hartford, Conn., when he retired from teaching and devoted the remaining years of his life chiefly to literary pursuits and to travel. For several years his winter home was in Washington City. He was a member of the New York Academy of Science (its president in 1893), of the American Association for the Advancement of Science, and one of the founders of the American Folk Lore Society. In 1897 he was president of the Library Association of Washington City; was president of the American Chemical Society in 1900, and was also a member of many other learned bodies in Europe and the United States, being a frequent contributor to their literary exercises and published transactions.

His varied contributions to contemporary literature cover more than 200 titles, among which may be mentioned The Scientific Correspondence of Joseph Priestley; Counting-Out Rhymes of Children; Catalogue of Scientific and Technical Periodicals, 1665–1897, and Select Bibliography of Chemistry, 1492–1902.

Respectfully submitted.

S. P. Langley,
Secretary of the Smithsonian Institution.

APPENDIX TO THE SECRETARY'S REPORT.

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report upon the condition and operations of the National Museum during the year ending June 30, 1904.

Ground was broken on June 15, 1904, for the new Museum building authorized by Congress in 1903, the first sod being turned by the Secretary of the Smithsonian Institution in the presence of the architects, the superintendent of construction, and the officers and employees of the Institution and its Bureaus. The excavation for the foundation and basement was well under way at the close of the fiscal year, and it is hoped that nothing will arise to interfere with the speedy construction of the building. This additional home for the National Collections will be about 551 feet long and 318 feet wide, exclusive of projections, thus exceeding in these dimensions all other buildings in the city of Washington except the Capitol. Its faces will be of light-colored granite, and its four stories will afford a floor area of about 9½ acres.

It is gratifying to be able to state that notwithstanding the great pressure of work in the scientific departments, caused by the preparation of exhibits for the Louisiana Purchase Exposition, very satisfactory progress has been made in all of the operations of the Museum.

The number of accessions received during the year was 1,703, or 60 more than in 1903, and comprise a total of 241,547 specimens. Profitable exchanges have been made with other institutions and with private collectors, the number of duplicate specimens utilized for this purpose exceeding 9,000.

The number of publications issued has been somewhat larger than usual, and their distribution, together with a large increase in the extent of the correspondence, has taxed to the utmost the office charged with these matters.

The reserve or study collections have been extensively used by investigators and students both in Washington and elsewhere, and more than 20,000 specimens have been sent to specialists for examination and report. The number of lots of specimens received for identification has been 975.

Buildings.—The roofs on the Museum building, and especially those covered with slate, have for a long period been in a very unsatisfactory condition, resulting mainly from the fact that they were constructed too cheaply in the beginning, and therefore not as substantially as they should have been. Through the contraction and expansion of the iron supports by changes in temperature, the slate coverings have never been kept tight, and in other parts there has been greater or less trouble in regard to leakage, which has caused a constant defacement of the inner walls and some injury to the contents of the building. It is now realized that the only proper remedy would be to substitute a new roof for the present one, but as this can not be done at present, an effort is being made to institute more substantial repairs than heretofore, though at the best they can only be considered as temporary. The tin

coverings, gutters, etc., do not present serious difficulties, though requiring extensive renovation. Experiments on the slate, however, have led to the trial of a covering of asphalt, burlap, and slag, which has thus far resulted so favorably that it is now proposed to treat all the slate roofs in this manner.

The archaeological exhibition hall, the large upper room in the Smithsonian building, which has been closed for some time on account of the extensive loosening and fall of plaster, has been entirely repaired and painted during the past year, but its opening to the public must be deferred for a while longer, or until its collections have been reinstalled. Many other repairs in both buildings have been made during the year, but they have been chiefly of a minor character.

The number of specimen cases constructed has amounted to 212, and of specimen drawers to 3,378, mainly to accommodate the extensive accessions of the year, derived in greater part from Government scientific surveys. The fittings of all kinds for the cases and for the mounting of specimens have called for a large amount of labor and material.

The pair of high-pressure steam boilers installed in the summer of 1901 for the heating of the two main buildings and the smaller adjacent buildings has continued to give entire satisfaction. The efficiency of the fire-protective system has been thoroughly tested during the year, with the result that some of the extinguishers of old pattern have been replaced by others of more modern make.

Organization and staff.—A few changes in the organization of the Museum have been made as follows:

The title of the "Division of Religions" has been changed to "Division of Historic Religions," with Dr. Cyrus Adler as honorary curator, and the former "Section of Historic Religious Ceremonials" has been abolished. That of the "Division of History and Biography" has been changed to "Division of History," with Mr. A. Howard Clark as honorary curator and Mr. Paul E. Beckwith as assistant curator, the "Section of American History" being omitted. The "Section of Electricity" has been abolished.

Mr. William H. Holmes, formerly head curator of the Department of Anthropology, but now Chief of the Bureau of American Ethnology, has accepted the position of honorary curator of the Division of Prehistoric Archeology, and Mr. J. D. McGuire that of collaborator in the same division. Other appointments have been as follows: Dr. Edward L. Greene, formerly professor of botany in the Catholic University of America, as associate in botany; Mr. Paul Brockett as custodian of the Section of Graphic Arts; Mr. Walter L. Hahn as aid in the Division of Mammals, and Mr. J. S. Goldsmith as superintendent of construction and labor, being a part of the service performed by the late Dr. J. E. Watkins, whose lamented death occurred on August 11, 1903.

A number of members of the scientific staff have severed their connection with the Museum, all at their own volition, to accept positions at higher compensation elsewhere. Among these were Mr. F. A. Lucas, curator of Comparative Anatomy, who has become curator in chief of the museum of the Brooklyn Institute of Arts and Sciences; Mr. Louis Pollard, assistant curator in the Division of Plants; Mr. Rolla P. Currie, aid in the Division of Insects; and Mr. W. C. Phalen, aid, and Mr. R. S. Bassler and Mr. Alvan Stewart, preparators, in the Department of Geology.

It may also be mentioned in this connection that Mr. Charles Schuchert, assistant curator of Stratigraphic Paleontology, attended the Ninth International Geological Congress, held at Vienna from August 20 to 27, 1903, as the representative of the Smithsonian Institution and the Museum; while in the same capacity Mr. Leonhard Stejneger, curator of Reptiles, Mr. Gerrit S. Miller, jr., assistant curator of Mammals, and Dr. C. W. Stiles, custodian of Helminthological Collections, will be present at the Sixth International Congress of Zoology at Berne during August of this year, and Mr. William H. Holmes at the Congress of Americanists to be held at Stuttgart

during the same month. Messrs. Stejneger, Miller, Stiles, and Holmes have also been designated by the Department of State as official representatives of the Government on the two occasions named.

Additions to the collections.—The number of separate lots of material received during the year was 1,703, comprising 241,547 specimens in all, or 5,000 more than the previous year. The total number of specimens recorded in all departments of the Museum is now 5,894,620 specimens, of which more than 4,100,000 belong to the Department of Biology, nearly 975,000 to the Department of Anthropology, and about 730,000 to the Department of Geology.

Collections sent by Dr. W. L. Abbott from the Malay peninsula, northern Sumatra, and the adjacent archipelago contain the most interesting additions in Anthropology, and in conjunction with his previous contributions from the same and other parts of Asia constitute an exceedingly valuable and unique feature of the ethnological exhibits. Dr. E. A. Mearns, U. S. Army, who has continued his scientific work in the Philippine Islands, presented collections of special interest obtained by himself during the campaign against the Moros. Another Moro collection, consisting of edged weapons, spears, and costumes, was received from Dr. R. B. Grubb, also of the United States Army. The very valuable collection of archeological objects obtained in Cuba, Trinidad, Grenada, Barbados, Dominica, Porto Rico, and other West Indian islands by Dr. J. Walter Fewkes, of the Bureau of American Ethnology, during the winter of 1903, has been transferred to the keeping of the Museum. It contains a very large variety of objects which will probably aid materially in solving the problem of the ancient relations between North and South America. The same Bureau has also deposited a large series of specimens recently taken from caverns, rock shelters, and village sites in the Ozark region of Missouri and Arkansas. A number of Tlinkit house posts and totem poles was obtained from Dr. George A. Dorsey, of the Field Columbian Museum, and a valuable lot of art objects from southwestern Alaska, consisting of carved clubs, knives, embroidered blankets, etc., from Lieut. G. T. Emmons, U. S. Navy. Some curious earthenware vessels from aboriginal graves in Argentina were presented by Mr. Felix F. Outes, of Buenos Aires, and several knives with handles and blades in one piece, as well as flint implements, from the temple of Osiris, Abydos, were contributed by the Egypt exploration fund.

The collections in prehistoric archeology have been enriched by a series of Egyptian stone implements presented by Mr. H. W. Seton-Karr, of England, and representing a type peculiar to the Fayum district, as well as by a large series of specimens chiefly from a few localities in the Miami Valley, and forming part of the bequest of the late I. H. Harris, of Waynesville, Ohio. The latter contribution also includes a typical series of earthenware vessels from mounds near Charleston, Mo.

To the recently established Division of Physical Anthropology have been added more than 2,000 crania and skeletons by transfer from the Army Medical Museum, 11 crania of Wasco Indians from the Fred Harvey collection, and other desirable specimens.

The additions to the historical collections have included a valuable series of relics presented by Gen. John Watts de Peyster, who has also made several contributions of important historical works; the gilt dress sword presented to Gen. Jacob Brown, by the State of New York, for valuable services during the Revolutionary war, donated by his grandson, Mr. Nathan Brown Chase; an oil portrait of George Catlin, painted by W. H. Fisk, R. A., in 1849, deposited by his daughter, Mrs. Louise Catlin Kinney; numerous relics deposited by the National Society of the Daughters of the American Revolution, and the sword and epaulettes worn by Gen. Alex. McComb, U. S. Army.

The technological exhibits have been materially increased; among the accessions of special interest being a collection of rifles, muskets, and other firearms of historical value, 615 in number, deposited by the Bureau of Ordnance of the War

Department; a collection of Morse telegraph keys, insulators, and other electrical apparatus, presented by the Pennsylvania Railroad Company; a collection illustrating the development of the hand camera, by the Eastman Kodak Company; a collection of sporting rifles of the kind used in this country prior to 1850, lent by Mr. Herman Hollerith, and a rare form of flintlock pistol with folding bayonet, presented by Mr. Paul Beckwith.

The accessions to the Department of Biology embraced 151,000 specimens, or nearly 41,000 more than the previous year. The collection of insects was increased by about 59,000 specimens, the herbarium by about 43,000, while the remaining 49,000 specimens were divided among the other divisions.

The most extensive of the zoological collections, in point of number of specimens, consisted of about 40,000 insects obtained in British Columbia by Dr. Harrison G. Dyar, assisted by Mr. Rolla P. Currie and Mr. A. N. Caudell. The Bureau of Fisheries transmitted large collections of land and fresh-water shells, reptiles, and crustaceans from Indiana and other States; a valuable series of marine mollusks, chiefly from Alaska; the types of recently described fishes from Japan, the Hawaiian Islands, etc.; fishes, crustaceans, and corals secured in connection with the Alaskan salmon-fisheries investigation of 1903, and 461 plants from Alaska and Oregon.

Especially worthy of mention are the important zoological contributions from the Mentawei Archipelago, Sumatra, and various islands off the eastern coast of Sumatra, obtained and presented by Dr. William L. Abbott. Thirty-one new forms of mammals and several new species of birds are represented in the collection from the archipelago, while those from eastern Sumatra also contain very valuable material, including numerous forms of birds and reptiles not previously received. Several valuable lots of zoological specimens from Minnesota and the Philippine Islands were donated by Dr. E. A. Mearns, U. S. Army. A large number of mammals, birds, reptiles, and fishes from the Bahama Islands were secured as the result of the expedition sent to those islands by the Baltimore Geographical Society, and of which Mr. B. A. Bean and Mr. J. H. Riley, of the Museum staff, were members. A valuable collection of birds' eggs and reptiles from Texas was transmitted by the Biological Survey of the Department of Agriculture.

Noteworthy among the mammals received were a specimen of a remarkable species of bat, *Euderma maculatum*, presented by Mr. E. O. Wooton, of Mesilla Park, N. Mex.; the first authentic specimen of a jaguar from the United States; a rare mouse-deer, *Tragulus stanleyanus*, obtained from M. Emile Deschamps; a collection of Old World mammals, obtained from W. Schlüter; a collection of Japanese mammals from Mr. T. Tsuchida; some rare forms of bats from the British Museum, and a collection of Colombian mammals from the American Museum of Natural History.

An interesting series of birds of the Philippine Islands was secured by exchange with the Museum in Manila. Mr. Homer Davenport, of East Orange, N. J., presented a number of young pheasants, and Mr. N. C. Brown, of Portland, Me., a well-prepared series of the birds of North Carolina. Four species of birds of paradise, new to the collection, were purchased. Dr. W. L. Ralph, of the Museum staff, and Gen. J. W. Barlow made generous contributions to the collection of birds' eggs, and series of rare Mexican eggs and of the eggs of the Hoactzin were purchased.

A collection of Japanese reptiles was presented by Dr. Hugh M. Smith, and some rare reptiles of southern Florida by Mr. E. J. Brown, of Lemon City, Fla. The Division of Fishes has received a large number of Japanese species from the Leland Stanford Junior University, and a well-prepared series of specimens from Puget Sound, donated by Dr. J. C. Thompson, U. S. Navy. A specimen of the Japanese shark, *Mitsukuria owstoni*, was purchased.

Hawaiian land shells and other invertebrates were received from Mr. H. W. Henshaw, of Hilo, Hawaii; Dr. R. E. C. Stearns, honorary associate in zoology, now residing in Los Angeles, Cal., presented an extensive series of west American shells,

and Mr. H. N. Lowe and Mrs. Blanche Trask, several lots of Californian shells; Mr. E. J. Court, of Washington, D. C., donated a representative series of the land shells of Maryland, Virginia, and the District of Columbia; Dr. Dwight Blaney about 300 shells dredged near Mount Desert, Me., and Mr. C. A. Davis, many Bermuda shells, including several cotypes. Among the specimens obtained by purchase was a large collection of Japanese land and marine mollusks, and land shells from the Pacific coast and the islands off California.

The Division of Marine Invertebrates received a collection of Mexican fresh-water crabs from the Biological Survey of the Department of Agriculture; crustaceans from Catalina and San Clemente Islands, presented by Mr. H. N. Lowe; cotypes of a species of shrimp and of a stomatopod crustacean from the National Museum of Brazil; several beautiful specimens of the Japanese precious coral from Dr. K. Kishinouye; and a collection of sea urchins, chiefly from the Gulf of Siam, from the Zoological Museum in Copenhagen.

The additions to the Division of Insects were numerous and valuable. Among those of greatest importance may be noted two lots of over 6,000 specimens from the Department of Agriculture; an extensive collection of Coleoptera, Lepidoptera, etc., made by Mr. E. A. Schwarz, in Texas; several lots of Philippine insects from Rev. W. A. Stanton, of Manila, and one from Mr. R. C. McGregor, of the Philippine Museum; a large miscellaneous collection from the grounds of the Washington Biologists's Field Club at Plummer's Island; and a valuable collection of Lepidoptera, from Mr. E. M. Anderson, of the Provincial Museum at Victoria, British Columbia. From foreign sources the following collections were received as gifts: Indian Hymenoptera from Maj. C. G. Nurse; Indian spiders from Prof. N. Jambunathan; Venezuelan beetles from Mr. Edward A. Klages; Peruvian insects from Mr. M. J. Pusey; and Norwegian Lepidoptera from Sir George Hampson, of the British Museum.

Of 555 accessions to the Division of Plants, the most valuable was the deposit made by Dr. E. L. Greene, of his collection of about 60,000 sheets of plants, and his entire botanical library. Next in importance was the gift by Mrs. T. A. Williams, of Memphis, Nebr., of about 15,000 plants from various parts of the United States. Mr. C. V. Piper, of Pullman, Wash., presented more than 600 plants from that State, and Mr. E. W. D. Holway, of Minneapolis, Minn., an interesting collection of Mexican plants. Important exchanges were made with the Philippine Bureau of Agriculture, the New York Botanical Garden, and the Royal Gardens at Kew, England. Sixty-eight botanical accessions were received from the Department of Agriculture, the most important comprising specimens obtained in Texas by Mr. Arthur Howell, in New Mexico and Oklahoma by Mr. Fred. G. Plummer, and in New Mexico by Mr. Vernon Bailey. Plants from Australia, Mexico, Nicaragua, Costa Rica, and from several of the States were acquired by purchase.

The most extensive additions to the geological collections were, as usual, received from the United States Geological Survey, prominent among them having been about 40,000 invertebrate fossils, mostly named and including a large amount of material on which Dr. William H. Dall and his assistants have been working for several years. The Survey also transmitted a series of 1,932 tertiary insects, assembled by Dr. Samuel H. Scudder, together with a number of original drawings. The acquisition of this material is believed to make the Museum collection of fossil insects the largest in the United States, if not in the world.

A collection of platiniferous rocks from the Demidoff mines in Russia was presented by Juarez Sponville; a series of rocks illustrating the occurrence and association of diamonds at the De Beers consolidated mines in South Africa, by Mr. Gardner F. Williams, manager of the mines; a rich nugget of native silver, by A. L. Pellegrin, of Nogales, Ariz., and a specimen of diamond-bearing gravel from Minas Geraes, Brazil, to which a small diamond was attached, by Dr. O. A. Derby, of São Paulo.

A fine mass of amethystine quartz, weighing about 400 pounds, was obtained from Ward's Natural Science Establishment, Rochester, N. Y.

The Division of Minerals was enriched by a large collection illustrating the occurrence and association of the zeolites and siliceous minerals of New Jersey, obtained through the assistance of Dr. W. S. Disbrow, of Newark, N. J., who also transmitted one of the first known crystals of American spodumene. Other important gifts were a specimen of pink spodumene, from Mr. F. M. Sickler; a series of artificial stones used in the gem trade, from Mr. Oscar T. Jonassohn; a cut turquoise from North Carolina, from Mr. Eugene A. Smith, and some fine specimens of smoky quartz from Messrs. A. P. Pohndorf and J. R. Wharton.

For the meteorite collection specimens illustrating the Trenzano fall, the Franceville iron, the Mukerop iron, and the Finnmarken pallasite have been acquired.

Of invertebrate fossils, the accession next in importance to that transferred by the United States Geological Survey was the last portion of the E. O. Ulrich collection, containing about 15,000 specimens, besides 500 lots of original types or of specimens that have been used for illustration. A series of Lower Silurian fossils, selected by Mr. Charles Schuchert while in Russia, was presented by the Imperial Academy of Sciences, of St. Petersburg, through the cooperation of Dr. Frederich von Schmidt, and a valuable donation consisting of nearly 600 specimens of Hamilton brachiopods was received from the Yale University Museum. By exchange with the Zoological Museum of the University of Copenhagen, more than a hundred specimens of identified European mesozoic and tertiary bryozoans were obtained.

To the collection of fossil vertebrates were added fine specimens of pterodactyl, ichthyosaurus, and teleosaurus; some fishes from the lithographic limestone, and a fossil skull of *Bison Alleni* from a placer deposit of frozen gravel, 25 feet below the surface. The object last mentioned was presented by Messrs. McLain and Ballou, of Rampart City, Alaska, and is especially noteworthy as being the first specimen of the species discovered in Alaska.

One hundred and thirty-two fossil plants collected in the Iowa anthracite beds were donated by Mr. C. W. Unger, of Pottsville, Pa., and 190 specimens of fossil plants from Illinois, Ohio, and other localities, forming part of the Carl Rominger collection, were also obtained.

Explorations.—But few explorations were carried on last year by members of the Museum staff, owing to the lack of funds. Dr. Walter Hough spent some time in Arizona and New Mexico, where he made a large collection of ethnological and archeological objects. The expedition sent to the Bahamas during the summer of 1903 by the Baltimore Geographical Society and Johns Hopkins University, under the direction of Dr. G. B. Shattuck, was accompanied by Mr. Barton A. Bean and Mr. J. H. Riley, who took an active part in the work of collecting and observation. Dr. Harrison G. Dyar and Mr. Rolla P. Currie were members of a party sent to British Columbia by the Carnegie Museum of Pittsburg. During a trip to Europe Mr. Charles Schuchert collected some valuable fossils, and while seeking material for the Louisiana Purchase Exposition Dr. George P. Merrill obtained many geological specimens for the Museum on the Pacific coast and in Canada and western Mexico.

Having been designated by the State Department and the Smithsonian Institution as delegates to the International Congress of Zoology at Berne, Switzerland, during the summer of 1904, Dr. Leonhard Stejneger and Mr. Gerrit S. Miller, jr., left Washington in May with the object also of making collections of mammals and reptiles in Europe, and of studying the specimens of these groups in the principal European museums. Short collecting trips, not necessary to mention here, were also made by other members of the staff.

There have been many explorations through which the Museum has profited, by private individuals and by other Government bureaus, of which a few may be noted. Dr. William L. Abbot has continued his field work in Sumatra, the Mentawei Archi-

pelago, and along the coast and on the islands east of Sumatra. In connection with the investigations of the Bureau of Fisheries, Dr. Hugh M. Smith has visited Japan, and Dr. B. W. Evermann, Prof. Charles H. Gilbert, and Prof. O. P. Jenkins have made extensive explorations in Hawaii. The natural history bureaus of the Department of Agriculture, and especially the Biological Survey, have made important collections in different parts of the United States.

Field work under the Bureau of American Ethnology, productive of collections, has been carried on by Dr. J. Walter Fewkes, in the West Indies, and by Mr. James Mooney, Mr. Gerard Fowke, Mrs. M. C. Stevenson, and Mr. J. R. Swanton, in the West. Reference should also be made to the important work conducted in the Philippine Islands by Dr. E. A. Mearns, U. S. Army, one of the most frequent contributors to the Museum collections.

Researches.—Of the material which reaches the Museum, a part has previously been studied and a part not, but the proportion either way would be difficult to state and varies from year to year. The act founding the establishment provides that the collections shall be arranged and classified, and therefore in selecting the caretakers, persons skilled in the various branches represented are chosen to the extent of the funds available. It is recognized that their first obligation is to look out for the safety of the specimens in their charge, and as the technical staff under pay is relatively small, attention to this duty consumes the greater part of their time. About one-half of the scientific staff, moreover, consists of volunteers, on whom the same demands can not be made, though some of these are equally attentive to the routine work. The scientific results accomplished each year by the Museum staff as a whole is, nevertheless, relatively extensive, comprising mainly the identification, labeling and description of specimens, and their classified arrangement in cases and drawers, so as to make them convenient for reference.

For a large part of the scientific work, however, assistance must be obtained from experts connected with other establishments. Entire groups of specimens may be assigned to individuals for working up, or advantage may be taken of researches in progress elsewhere to have material of greater or less extent identified, and visiting scientific men are often willing to spend some time upon such parts of the collections as come within their knowledge. It is impossible within the limits of this report to account for all the work of this character carried on during the past year, but the number of persons concerned, not including those on the Museum staff, was in the neighborhood of 200, and over 20,000 specimens were sent away for study. The cooperation with persons living elsewhere is far greatest in connection with the Department of Biology, whose varied collections have long attracted widespread interest, and have led to many extensive and important investigations.

Exchanges.—Many exchanges of duplicate specimens with other institutions and with individuals have been made with satisfactory results for the Museum. The establishments abroad with which such transactions were most extensively carried on were the Albany Museum at Grahamstown, South Africa; the K. K. Naturhistorisches Hofmuseum at Vienna; the Zoological Institute of the Imperial University at Vienna; the Botanical Museum at Berlin; the Museum of Natural History at Paris; the Zoological Museum of the University of Copenhagen; the Royal Frederick University of Christiania, and the Royal Botanic Garden at Sibpur, Calcutta.

The distribution of duplicates to colleges and other educational institutions throughout the country has been limited during the year to fishes, marine invertebrates, and geological specimens illustrating rock weathering and soil formation, of which 97 sets have been sent out. Some duplicate sets of fossils are now being prepared for the same purpose. The applications for such material to aid in the teaching of natural history are far more numerous than can be supplied, the assistants qualified to select and label the specimens being generally too busily occupied in other ways. The

present crowded condition of the Museum also interferes with the overhauling of the collections, which is necessary in picking out the duplicates.

The exhibition halls.—Although no increase in the amount of exhibition space is possible in the present building, yet by resorting to various expedients and removing specimens to storage a little more room may be obtained here and there for the display of exhibits or single objects which it is thought may prove of greater interest to the public.

In the Department of Anthropology a few cases have been added in the northwest court gallery for an exhibit of Indian baskets, this subject having gained special prominence through the publication of Prof. O. T. Mason's recent paper. Space has also been provided for a portion of the splendid Malaysian collection received from Dr. William L. Abbott. A collection of lamps, a typical series of guns, and three table-cases containing revolvers and pistols of various dates and makes have been arranged in the east hall, and a number of ethnological objects from the Philippine Islands in the gallery of the northwest court. The collection of musical instruments has been partly reinstalled. Among the technological objects has been placed the cylinder of the Hornblower engine, the first steam engine put together on the western continent, having been imported from England in 1753.

The groups of ethnological lay figures returned from recent expositions have been installed wherever a place could be found for them, some having been arranged in the lecture hall.

But little was done toward preparing new exhibits in the Department of Biology, as other and more urgent work has interfered. Some of the more valuable birds have been remounted, and four groups of game birds have been installed in two new cases at the entrance to the Smithsonian building. The unoccupied cases in the southeast range set apart for casts of fishes will soon be filled by new preparations now in course of making. A beginning has been made toward the installation of a series of specimens illustrating the mollusk fauna of the District of Columbia, one case having already been completed.

To the display collection in the Department of Geology have been added the skulls of a new genus of Ceratopsia, and of *Diplodocus* and *Trachodon*, and also a mounted skeleton of *Syornis casuarinus* from New Zealand. The Claosaurus, mentioned in last year's report, is exhibited near the south wall of the southeast court.

Visitors.—The number of persons who visited the Museum building during the year was 220,778, and the Smithsonian building, 143,988, being an approximate daily average of 705 for the former and of 460 for the latter. The decrease as compared with the previous year was a result of the large attendance at the time of the encampment of the Grand Army of the Republic in October, 1902. Since the first occupation of the Museum building in 1881, the total number of visitors recorded has been over 8,000,000.

Meetings and lectures.—On February 20 and 27, and March 5, 12, and 19, a series of lectures was given in the lecture hall under the auspices of the Biological Society of Washington by Mr. Charles H. Townsend, Mr. Gifford Pinchot, Mr. E. W. Nelson, Prof. Henry F. Osborn, and Dr. C. Hart Merriam, the average attendance having been about 1,000. The closing exercises of the Naval Medical School and the Army Medical School were held in the same place on March 21 and April 5, respectively. The American Oriental Society had its annual meeting in the lecture hall on April 7 and 8, and the National Academy of Sciences from April 19 to 21. On June 13 an illustrated lecture entitled "Botanical Tramps with a Camera" was delivered by Dr. C. E. Waters, of Johns Hopkins University, under the auspices of the Wild Flower Preservation Society of America.

Publications.—The publications issued during the year comprised 6 volumes and 59 technical Proceedings papers, being an increase over previous years, due partly to delays in completing volumes belonging to 1903. The 6 volumes referred to were Nos. 25, 26, and 27 of the Proceedings, the Annual Reports for 1901 and 1902, and

Prof. C. C. Nutting's monograph on the Sertularian hydroids, forming part 2 of Special Bulletin No. 4.

The three volumes of Proceedings contained in all 110 papers, of which 39 relate to fishes, 19 to insects, 18 to marine invertebrates, 10 to birds, and the remainder to mammals, mollusks, plants, reptiles, fossils, and meteorites.

The Appendix to the Report for 1901 was made up of five papers, as follows: "Report on the Exhibit of the United States National Museum at the Pan-American Exposition, Buffalo, N. Y., 1901;" "Flint Implements and Fossil Remains from a Sulphur Spring at Afton, Ind. T.," and "Classification and Arrangement of the Exhibits of an Anthropological Museum," by Mr. William H. Holmes; "Archeological Field Work in Northeastern Arizona," by Dr. Walter Hough, and "Narrative of a Visit to Indian Tribes of the Purus River, Brazil," by Prof. J. B. Steere.

The Report for 1902 contained an elaborate paper by Prof. O. T. Mason on "Aboriginal American Basketry: Studies in a Textile Art without Machinery"; one by Dr. Leonhard Stejneger, entitled "The Herpetology of Porto Rico"; and one by Mr. F. V. Coville, entitled "Wokas—Primitive Food of the Klamath Indians."

Several papers by members of the Museum staff on material contained in the Museum were, by permission of the Secretary, printed in various journals, and a number were also published in the quarterly issue of the Miscellaneous Collections of the Smithsonian Institution.

The Annual Report for 1903, now ready to go to press, will have a paper by the Assistant Secretary on the buildings occupied by the National Collections, and a translation of the three papers by Dr. A. B. Meyer, director of the Royal Zoological Anthropological-Ethnographical museums in Dresden, on the principal museums of New York State, Chicago, and several European countries.

Library.—The library of the National Museum has received as a gift from Prof. Otis T. Mason, in addition to one made some years ago, about 2,000 pamphlets, separates, and bound quarto volumes mostly on anthropological subjects, for which a special bookplate has been provided. The Museum has also received from Dr. Edward L. Greene his entire botanical library, which has been placed on deposit for a period of ten years in connection with his botanical collections.

The aggregate of additions to the Museum library for the year amounted to 1,504 books, 3,187 pamphlets, and 700 parts of volumes.

Expositions.—The exhibits prepared by the Museum for the Louisiana Purchase Exposition were properly arranged before the opening day, and the zeal and activity displayed by the curators, preparators and others engaged in their preparation, shipment, and installation are highly commendable. The collections are grouped under the three general heads of anthropology, biology, and geology. A brief account of them will be found in the Museum report for this year, while the official report of Dr. F. W. True, representative of the Institution and the National Museum, will be published later.

Congress at its last session made provision for the celebration of the one hundredth anniversary of the exploration of the Oregon region by Capts. Meriwether Lewis and William Clark, including a Government exhibit, for which the sum of $200,000 was appropriated, besides $250,000 for a suitable building. The bill S. 276, introduced by Senator John H. Mitchell on November 11, 1903, was approved by the President on April 13, 1904.

Respectfully submitted.

Richard Rathbun,
Assistant Secretary in charge of the U. S. National Museum.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

August 1, 1904.

Appendix II.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

Sir: I have the honor to submit the following report on the operations of the Bureau of American Ethnology for the fiscal year ending June 30, 1904, conducted in accordance with the act of Congress making provisions for continuing researches relating to the American Indians under the direction of the Smithsonian Institution. The work has been carried out, with some minor modifications, in accordance with plans of operations submitted, the first on June 11 and the second on September 26, and duly approved by the Secretary. The first plan provided for the month of July only. The Smithsonian Institution was engaged in an examination into the affairs of the Bureau, and until this was brought to a conclusion it was not regarded as feasible to formulate plans for the year. The plan for July was extended to the months of August and September, and on the 1st of October a plan of operations for the remaining nine months of the year was submitted and duly approved by the Secretary.

On July 31 Mr. W J McGee, ethnologist in charge, tendered his resignation, which was accepted, and the position of ethnologist in charge was discontinued.

The research work has been carried forward by a permanent force of eight scientific employees, and a number of temporary assistants have been engaged for periods of varying lengths, both in the office and among the tribes. Field operations were interfered with to some extent during the early months of the year, the presence of the various ethnologists being required in the office in connection with the examination referred to above.

During the year five members of the staff prosecuted systematic researches in the field, and the sections of the country visited by these and by special assistants include Alaska, British Columbia, Oregon, California, New Mexico, Oklahoma, Indian Territory, and the West Indies. Mr. James Mooney was in the field eleven months, Mrs. M. C. Stevenson nearly six months, Dr. J. W. Fewkes five months, Dr. John R. Swanton six months, and Mr. H. H. St. Clair, 2nd, four months—a total of thirty-two months.

The researches have dealt more or less directly with a large part of the anthropological field, and more especially with the history and archeology of the pre-Columbian tribes of the West Indies; with the social, religious, and esthetic activities of the tribes of the Great Plains; with the mythology, social institutions, ceremonies, and art of the Pueblo Indians; with the languages, mythology, and art of the Alaskan tribes, and with the languages of certain vanishing tribal remnants dwelling in northern California. The collecting of ethnological and archeological specimens and of data relating thereto, especially in the field of symbolism as embodied in art, has received special attention from the field workers.

The scientific researches and work carried on in the office were of exceptional importance, particularly in connection with the preparation of a cyclopedia of the Indian tribes, the writing of a handbook of American languages, the compilation of an archeological map of the United States, the study of visiting delegations of Indians, and the preparation of exhibits for the Louisiana Purchase Exposition. The editorial and library work, the cataloguing of manuscripts, the preparation of illustrations, and the general clerical work have been carried forward in the usual manner.

It was found impracticable, on account of the restricted resources of the Bureau, to provide for all the branches of work referred to in the plan of operations for the year. The transcription of the Motul Dictionary was not taken up, and the cataloguing of books and photographic negatives has not received the attention it deserves. The lack of a permanent force sufficient to cover all the ground was, however, compensated for in part by the temporary employment of special expert help in directions where such help could be made most effective.

EXPOSITION WORK.

The preparation of an exhibit for the Louisiana Purchase Exposition, begun during the preceding year, was continued, and completed shortly after the opening of the exposition in May. This work was under the personal supervision of the Chief, who at the same time had charge of the preparation of an extensive exhibit for the Department of Anthropology of the United States National Museum. The allotment of $2,000, made by the Government Board for the Bureau exhibit, was too small to warrant the assemblage of an extensive display; moreover, the space assigned was extremely scant, and it was decided to confine the exhibit to illustrations of the present field researches of the ethnological corps of the Bureau.

Seeking a subject that would be well within the range of the Bureau's legitimate field and yet susceptible of effective presentation by means of objective material, it was decided to take up and illustrate as the chief topic the mythic symbolism of various tribes as embodied in their decorative arts. Prominent among the concepts thus embodied are the various forms of animal and plant life, clouds, lightning, rain, sun, moon, and stars, as well as various monsters existing only in the imagination. These motives are interwoven with the thought and life of the people, and are introduced freely into their various arts. The forms taken by them are exceedingly varied, undergoing modifications with the different peoples, and taking distinct forms in each art according to the nature and form of the object, the method employed in execution, and the purpose in view.

In selecting the exhibits only the most important symbolic concepts of the tribes represented were chosen, and for each of these concepts a group of exhibits was assembled, consisting of a limited number of specimens of native workmanship in carving, modeling, painting, and engraving, and a series of the native designs drawn out in colors on a flat surface and associated with the specimens in the exhibit as a means of further elucidating the strange modifications everywhere displayed.

The series of motives selected to illustrate the symbolic decoration of the Zuñis include the bird, the butterfly, the cornflower insect, the dragon fly, the serpent, the frog and the tadpole, and the mountain lion; the human form and various monsters; vegetable forms; and sundry cosmic phenomena, such as clouds, lightning, rain, sun, moon, stars, and the planets. Doctor Swanton selected from the art of the Northwest coast tribes a series of very interesting subjects, including the killer whale, the hawk, the eagle, the thunderbird, and other monsters of the land and the sea. Doctor Fewkes presented the very artistic symbolism of the ancient tribes of Tusayan in series of illustrations, including the human form, the serpent, the mountain lion, the frog and tadpole, the butterfly, the bird, the sunflower, and the heavenly bodies.

These exhibits were supplemented by a series of designs and objects selected by Dr. Franz Boas to illustrate the varied symbolism associated with a given motive or design by different tribes and peoples.

In addition to these systematic exhibits, two other important collections were presented. The archeological researches of Doctor Fewkes in the West Indies were represented by a large series of typical relics of art in stone, bone, shell, wood, and clay, selected from the extensive collections made during three winters' research

among the islands. This series is without question the most complete yet brought together to represent the pre-Columbian culture of the Carib and Arawak peoples, who were practically exterminated by the Spanish invaders. Mr. Mooney, who is engaged in the study of the heraldry system of the Great Plains tribes, undertook to prepare a series of exhibits illustrating this heretofore undeveloped branch of research. The exhibit consists of shields and models of shields and tipis embellished with the heraldic symbols of the native owners, skins showing elaborate designs in brilliant colors executed by native artists, and numerous other specimens having a bearing on this phase of the culture of the Great Plains tribes.

The preparation of an extended exhibit for the National Museum gave the Chief the opportunity of assembling a large series of exhibits illustrating the higher achievements of the American race in various branches of art, including architecture, sculpture, plastic art, carving, basketry, featherwork, and weaving. A leading feature of the work consisted of restorations of a number of the great ruined buildings of Mexico and Yucatan. Five models of buildings were made: One on a scale of one-twelfth, one on a scale of one-eighteenth, and three on a scale of one twenty-fourth, and much time and research were expended in collecting data and in determining the details of construction and embellishment. Working plans for use in the building of these models were prepared by Mr. De Lancey Gill, and the models were constructed by Mr. H. W. Hendley and Mr. W. H. Gill.

FIELD WORK.

Mr. James Mooney, ethnologist, remained in the field during nearly the entire fiscal year, dividing his time between the Kiowa and the Cheyenne, with their associated tribes in western Oklahoma, in accordance with the existing joint agreement between the Bureau and the Field Columbian Museum. The two tribes referred to occupy adjoining reservations recently opened to white settlement, with agencies about 100 miles apart.

During July, 1903, Mr. Mooney was operating chiefly in the Cheyenne camp, spending a week in attendance at the great annual sun dance, where he succeeded in obtaining the first photographs ever made of the skull-dragging ceremony, and obtained for the National Museum the sacred buffalo skull used on the altar of the dance. Shortly afterward he was recalled to Washington, where he remained until October, returning to the field in time to witness the tomahawk dance of the Arapaho—an interesting ceremony held only at intervals of several years on the occasion of the promotion of the young men of a certain military society from a lower to a higher degree. Headquarters having been temporarily established at Darlington, the Cheyenne-Arapaho Agency, the winter months were spent in gathering additional Cheyenne information and in putting the final touches on a series of Kiowa models to be included in the Bureau's exhibit at the Louisiana Purchase Exposition. Early in March Mr. Mooney removed to his permanent headquarters at Mount Scott, in the Kiowa country. Work was continued on the exposition exhibit, which was shipped to St. Louis before the close of the month. About the middle of June he was instructed to proceed to St. Louis to complete the installation of this material; and, after spending a number of days in the study of the aboriginal exhibits of the exposition, he returned to the Kiowa country to continue his researches there.

Dr. J. W. Fewkes, ethnologist, remained in Washington during the first half of the year, engaged in the completion of his report on the previous winter's field work in Porto Rico and Santo Domingo, and in January, 1904, he again proceeded to the West Indies with instructions to make a reconnaissance of the great chain of islands connecting Florida with the eastern shore of Venezuela for the purpose of obtaining a general view of the antiquities and remaining tribal remnants. In January Doctor Fewkes reached Cuba, where he spent six weeks examining local collections, espe-

cially those in Havana and Santiago; he also visited Matanzas, Santa Clara, and Puerto Principe, and made excursions from the city of Santiago to settlements where a few Indians still lived. The small collections of prehistoric objects obtained in eastern Cuba were found to resemble those of the neighboring island of Santo Domingo, but to differ distinctly from those of the western extremity of the island. From Santiago he proceeded by the way of Jamaica to Trinidad, where he remained three weeks and gathered a small collection of archeological and ethnological objects and obtained data regarding the former inhabitants of the island and the present condition of survivors now living in the town of Arima. Here he obtained some information regarding the "fire walk," or the "fire pass," of the cooly residents of the island. From Trinidad he proceeded along the Lesser Antilles to Porto Rico, remaining, respectively, one or more days at Barbados, Grenada, St. Vincent, and St. Thomas, and obtaining prehistoric objects at several of these islands.

March and April were mainly spent by Doctor Fewkes on the southern side of the island of Porto Rico, visiting caves and shell heaps and other sites of prehistoric occupation. Extensive shell heaps were found at Cayito, near Salinas, and at the Coamo baths on the estate of Señor Usera. Several caves showing evidence of former occupation were found near Ponce. He purchased in Ponce the important collection of Señor Neumann, containing several stone collars, rare idols, complete pieces of pottery, and other objects. The whole collection made by Doctor Fewkes, including ethnological and archeological objects, numbers 630 specimens.

Since his return to Washington in May, Doctor Fewkes has been occupied with the preparation of a final report of his expeditions to the West Indies during the last three years.

Mrs. M. C. Stevenson, ethnologist, was engaged during the first six months of the year in completing her monograph of the Zuñi Indians and in preparing it for the press. In January she set out for New Mexico with the view of continuing her researches in certain directions, especially with respect to the relation of the Zuñi people to other tribes of the general region. Chief attention was given to the mythological system and to the ceremonial dances, which followed in quick succession during the late winter and the early spring months.

Mrs. Stevenson found the people of Zuñi much changed in recent years. The former gentleness of character and the marked courtesy of the primitive aborigines has entirely disappeared, save with a few of the older men and women, the desire of sordid gain engendered by contact with the whites outweighing every other motive.

Mrs. Stevenson was commissioned to collect material illustrative of her researches in Zuñi, to form part of the Bureau's exhibit at the Louisiana Purchase Exposition, the special topic being the religious symbolism embodied in the various arts, such as pottery, textiles, basketry, in costumes, altars, images, and other ceremonial objects. Her study of this subject, heretofore much neglected, was thorough, and the significance of nearly every symbol now used by the Zuñi was obtained. She observed that, while the officers of the secret fraternities have a thorough understanding of the symbolism associated with their altars, few persons know the meanings of the designs employed in pottery and the other useful arts, the artists themselves having little appreciation of the poetic imagery associated with the various figures. Mrs. Stevenson believes that the original significance of the decorative motives of the Zuñi people will soon be lost by them.

Aside from her systematic researches, a number of special subjects were investigated by Mrs. Stevenson, including the irrigating system of the Zuñi at Ojo Caliente, the manufacture and use of the native dyeing materials, the preparation of pigments, etc.

Early in August Dr. John R. Swanton, ethnologist, handed in a typewritten copy of the Haida texts obtained at Skidegate, Queen Charlotte Islands, during the winter

of 1900–1901, with accompanying translations. Subsequently he was engaged in copying and translating a second set of texts obtained at Masset, Queen Charlotte Islands, during the same expedition.

On December 16 Doctor Swanton returned to the Northwest to engage in field work, particularly among the Tlingit Indians of the Alaskan coast. From January 9 to March 21 he was at Sitka among the northern Tlingit, and from then until May 5 among the southern members of that family. On the way thither he engaged in some incidental work among the Haida, and during the season he collected about one hundred Tlingit myths, as well as much ethnologic material in other branches. One of Doctor Swanton's main objects in this expedition was to define the relations between the Haida and Tlingit peoples, looking to the possibility of a genetic relationship between them. A final conclusion on this point can not yet be given, but it was discovered that many of the resemblances noted between the two languages are due to an early residence of the Tlingit opposite the Haida on the coast now occupied by the Tsimshian. This fact, already partially recognized, and now practically demonstrated by Doctor Swanton, results in limiting the origin of much of the culture on this coast to the immediate neighborhood of Hecate Strait, northern British Columbia. An important contribution to the general subject of clan organization was made by the discovery of a small Tlingit group which practiced marriage with either of the two great clans.

Since his return to the office Doctor Swanton has been engaged, first, in revising the Tlingit material for the Cyclopedia of Indian Tribes in the light of the fresh information gained during his recent trip; and, second, in copying the texts taken among the Tlingit.

Mr. H. H. St. Clair, 2nd, special assistant in Philology, visited northern California and southern Oregon early in the year for the purpose of collecting data among the Rogue River, Coos, and other small tribal remnants, of which a few individuals survive in that region, and a number of valuable vocabularies were secured.

OFFICE WORK.

Mr. J. N. B. Hewitt, ethnologist, has continued the preparation and proof-reading of part 1 of his monograph on Iroquoian cosmology, which is to appear in the Twenty-first Annual Report. The reading of the galleys of the interlinear translation and the free translations into English of the Onondaga, the Seneca, and the Mohawk versions of this cosmology occupied a large part of his time during the year. Extensive revision was required on account of the premature transmission of the manuscript to the printer in 1902. This caused much delay, but it was considered advisable to permit the delay rather than to have the paper published in a form unsatisfactory to the author.

As custodian of linguistic manuscripts, Mr. Hewitt, assisted by Miss Smedes, continued the work of revising and bringing up to date the card catalogue of the linguistic and other manuscripts in the archives of the Bureau. This card catalogue was originally prepared in 1896–97 by Mr. Hewitt, with the assistance of the late Rev. J. Owen Dorsey, and in this work the manuscripts were classified under three main heads: First, the author or collector; second, the tribe or band-village; and third, linguistic stock—all under one alphabet. The cross-reference catalogue of the names of tribes and villages noted in the manuscripts is of very great use for the purpose of comparison and research and for determining the number and distribution of these manuscripts among the various stocks. In the present revision the work consists in making a duplicate copy of the card descriptive of the manuscript, which duplicate is pasted on the jacket or package containing the manuscript. A number is affixed to the original card, to the duplicate, and to the manuscript itself for the purpose of ready identification. New cards are being made for manuscripts acquired since the completion of the original catalogue in 1897. This scheme

has been applied to the manuscripts belonging to the Algonquian, the Athapascan, and the Iroquoian stocks. The work on these stocks is far advanced. All the cards of the original catalogue have been thus copied in duplicate.

Previous to the death of Maj. J. W. Powell, the late Director of this Bureau, the linguistic material, chiefly Shoshonean, which was collected personally by him in the field, was not placed in the archives of the office; but since that time this material has been incorporated with that already contained in the archives. A part of this material is still uncatalogued.

Mr. Hewitt has been called upon to do considerable work on the Iroquoian stock for the Dictionary of Indian Tribes, and much of the correspondence of the Bureau relating to linguistics has been placed in his hands.

During the year Dr. Cyrus Thomas, ethnologist, was engaged mainly on the Dictionary of Indian Tribes, under the direction of Mr. F. W. Hodge. The work consisted in preparing for final editing some of the families not finished at the commencement of the year, in reexamining the cards which had been previously passed over (to N) for the purpose of inserting any omitted titles and cross references, and in taking general care of the Dictionary cards. During the early part of the year considerable time was devoted by Doctor Thomas to the reading of final proofs of his second paper on the Maya calendar systems, which is to appear in the Twenty-first Annual Report.

Dr. A. S. Gatschet was engaged during the year in his linguistic work, mainly on his Algonquian texts, and some advance has been made in the compilation of his dictionary and grammar of the Peoria language. In addition, Doctor Gatschet has been called upon for information in his particular field for correspondents of the Bureau.

SPECIAL RESEARCHES AND WORK.

Under the direction of Dr. Franz Boas, honorary philologist of the Bureau, considerable progress has been made in the preparation of the Handbook of American Languages. Doctor Boas has not been able to devote any great portion of his own time to the work during the year, but it has been fully outlined, and a number of collaborators have begun the preparation of special papers. The introductory chapters of the work are assigned to Doctor Boas.

Mr. F. W. Hodge, of the Smithsonian Institution, has continued in charge of the Cyclopedia of Indian Tribes, and substantial progress has been made in its compilation. Much time has been consumed in revising and verifying the work of former years and in bringing the whole up to a uniform standard of excellence. Mr. Hodge has been assisted by Dr. Cyrus Thomas, ethnologist; Mr. Frank Huntington, editorial assistant, and Mrs. Nichols, typewriter, and has received contributions from numerous authors, including members of the Bureau and others intrusted with the treatment of special topics. The Cyclopedia work has been delayed by the lack of sufficient funds for the employment of skilled assistants.

Dr. Stewart Culin, of the Museum of the Brooklyn Institute of Arts and Sciences, has completed and handed in his monograph on American Indian games, and this great work was placed in the hands of the editor of the Bureau at the close of the year.

The plan of operations for the year included the provision that the Bureau should undertake the preparation of a measure for the preservation of our national antiquities, for submission to Congress. The Institution had previously interested itself in this subject, and in order that it might be prepared with a knowledge of what Governments of other countries had done in this direction, it was determined to make a study of the entire subject, and Mr. J. D. McGuire was temporarily employed to make investigations and formulate a measure. This step was taken, and the measure was in due course presented in the House and Senate. In prosecuting this work translations were made of the laws of various countries, including Mexico, France,

Germany, Italy, Sweden, Egypt, and Turkey, and others were thoroughly studied. Mr. McGuire also compiled much material relating to governmental support of anthropologic science in various countries. Later he took up and made much progress in the preparation of an archeological map of the United States, devoting his attention chiefly to the middle Atlantic coast section.

Each year, especially during the winter season when Congress is in session, numerous delegations of Indians visit Washington. It has been customary to have photographs made of members of these delegations in the Bureau laboratory, but heretofore the work has not been systematized. As proposed in the plan of operations, careful attention was given to this subject during the year. Mr. Andrew John, an Iroquois Indian, resident in the city, was employed to interview and make the acquaintance of all delegations on their arrival, with the view of conducting them to the laboratories of the Bureau and the National Museum, where arrangements were made to have measurements and photographs taken, and plaster masks also made of all who were willing to submit to the process. In the absence of proper laboratories in the Bureau for all save the photographic work, the delegations were in the main conducted to the laboratories of the National Museum, where every facility was afforded. The results of the year's work have been most satisfactory: One hundred and ten 8 by 10 negatives were made by Mr. Smillie and his assistants; measurements of 32 individuals were taken by Dr. Aleš Hrdlička in the Physical Laboratory; and masks of 20 individuals were made by Mr. William Palmer. The following is a list of the principal delegations, with the numbers conducted to the laboratories in each case:

Yankton Sioux	3	Osage	5
Iowa	5	Yakima	3
Muskogee Creek	5	Sisseton Sioux	4
Sac and Fox	2	Oglala Sioux	2
Nez Percé	2	Yankton Sioux	11
Osage	4		

COLLECTIONS.

The collections of ethnological and archeological specimens made during the year are exceptionally important. A special effort was made to obtain material for the purpose of illustrating the researches of the Bureau at the Louisiana Purchase Exposition. Valuable additions along this line were obtained by Doctor Fewkes in the West Indies, by Mrs. Stevenson in the Pueblo country, by Doctor Swanton in Alaska and British Columbia, and by Mr. Mooney in Oklahoma and Indian Territory. Seven hundred and seventy-eight specimens have been transferred to the National Museum, and such of these as were required for the purpose were sent to the exposition. Other collections were forwarded directly to the exposition and have not been transferred.

In order that collections made by the Bureau may receive immediate attention with respect to preservation from moths and other insects, and with the view of having them properly and promptly catalogued, they are, on arrival in Washington, placed in the hands of the head curator of anthropology of the National Museum, who has at hand all necessary facilities for preservation and record. It is understood, however, that these collections are at all times to be at the disposal of the Bureau for purposes of study and illustration. In all, about 1,000 specimens, mostly of exceptional value, have been acquired during the year.

ILLUSTRATIONS.

The work of the illustrations division remained in charge of Mr. De Lancey Gill. Illustrations for two annual reports—the Twenty-third and Twenty-fourth—and for Bulletin 28 were edited and prepared for transmittal to the Public Printer; 137

drawings for the illustration of these volumes were made, and 900 engravings for the same were examined and necessary corrections indicated. In the photographic branch of the work, wherein Mr. Gill was assisted, as heretofore, by Mr. Henry Walther, 166 negatives were taken, 132 films exposed in the field were developed, and 1,373 prints were made.

Mr. Gill was also called upon to assist in preparing exhibits for the Louisiana Purchase Exposition, and made during the year detailed plans required in the construction of models of the Temple of the Cross at Palenque, and the Castillo at Chichenitza, and also of two models illustrating in actual dimensions the remarkable sculptural embellishments characteristic of the ancient Mayan architecture.

PUBLICATIONS.

The Twentieth Annual Report and Part I of the Twenty-second have been issued during the year, the former in March and the latter in May, 1904. The Twenty-first and Part II of the Twenty-second are in press. The Twenty-third was submitted for publication on February 23, and Bulletin 28 was sent to the Public Printer on March 31, 1904.

Publications are sent to two classes of recipients: First, regularly, without special request, to working anthropologists, public libraries, scientific societies, institutions of learning, and to other persons or institutions able to contribute to the work of the Bureau publications, ethnologic specimens, or desirable data; second, to other persons or institutions in response to special requests, usually indorsed by members of Congress. During the year 1,946 copies of the Twentieth Annual Report have been sent to regular recipients, and 2,500 miscellaneous volumes and pamphlets have been distributed in response to about an equal number of special requests. More than 250 of these requests have come through Congressmen, and about 500 volumes have been sent in response. One hundred and fifteen copies of Part I of the Twenty-second Annual Report have been sent out.

EDITORIAL WORK.

Mr. Herbert S. Wood has had charge of the editorial work during the year, being assisted in several instances by Dr. Elbert J. Benton, Mr. E. G. Farrell (courteously detailed for the work by the Government Printing Office), and Mr. William Barnum. The editorial work for the year has consisted chiefly in the reading of proofs of the Twenty-first and Twenty-second Annual Reports, and the preparation for printing of the Twenty-third Annual Report.

LIBRARY.

At the time of the removal of the Bureau of American Ethnology from the United States Geological Survey building in 1893, the volumes belonging to the Bureau numbered about 2,500. Through exchange and purchase the growth of the library has been, on the whole, satisfactory. The library now contains 12,165 bound volumes, about 6,500 pamphlets, and a large number of periodicals. In the purchase of books care has been used to add only such works as bear on the subject of anthropology with special reference to the American Indians, although volumes relating to kindred subjects are received through exchange.

The accessions for the year number 302 bound volumes, about 500 pamphlets, and the regular issues of more than 500 periodicals.

CLERICAL WORK.

The clerical work of the Bureau has been intrusted largely to Mr. J. B. Clayton, who on June 1, 1904, with the approval of the Civil Service Commission, received the designation of head clerk. Mr. Clayton has had personal charge of the financial

work of the Bureau, including the purchase of supplies and the preparation of accounts.

The clerical work during the year included the registration and cataloguing of letters, the preparation of replies to letters, and the keeping of miscellaneous records. The method described in the report for the previous year as having been adopted has been employed during this year, and the clerical work of the Bureau is kept up to date. As a rule, letters are answered the same day that they are received, and it is only where technical information is called for that there is any delay whatever. The letters in regard to publications, finances, field work, and miscellaneous information cover 2,835 pages in the press-copy letter books.

Miss E. R. Smedes has given excellent service in connection with the general correspondence of the Bureau. The clerical work in the Library has been satisfactorily attended to by Miss Ella Leary.

The very considerable work involved in the care and distribution of publications has been in charge of Miss May S. Clark, who has efficiently met the Bureau's needs in this direction.

Mrs. F. S. Nichols was certified by the Civil Service Commission for temporary work in connection with the Dictionary of Indian Tribes, and Misses Postley, Stratton, and Taliaferro were employed for brief periods in the same work.

PROPERTY.

The property of the Bureau is comprised in seven classes, as follows:

Office furniture and appliances.
Field outfits.
Ethnological manuscripts and other documents.
Photographs, drawings, paintings, and engravings.
A working library.
Collections held temporarily by collaborators for use in research.
Undistributed residue of the editions of Bureau publications.

Respectfully submitted.

W. H. Holmes,
Chief of Bureau.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

July 15, 1904.

Appendix III.

REPORT ON THE OPERATIONS OF THE INTERNATIONAL EXCHANGE SERVICE.

Sir: I have the honor to submit the following report relating to the operations of the International Exchange Service during the year ending June 30, 1904:

The term "International Exchanges" has been applied by the Smithsonian Institution almost since its foundation to the interchange of its publications for those of scientific societies and establishments in foreign countries. A liberal distribution of the works published at the expense of the Smithson fund was one of the principal means adopted in the early plans of the Institution for administering that part of the bequest of its founder relating to the "diffusion of knowledge among men."

In order to carry out a systematic exchange of large quantities of books it was necessary to enlist the cooperation of institutions and individuals in the populous centers of the world, and as it became known that such arrangement existed, first one then another society and finally the United States Government asked the Smithsonian Institution to perform a similar service in exchanging its publications, until the expense became a heavy tax on the income of the Institution.

In 1881 Congress made a small appropriation to the Smithsonian Institution in aid of the Exchange Service, and has since continued to make an annual appropriation, though at no time has it been sufficient to cover the extire expense of the service, consequently the Institution has been obliged to request a partial reimbursement of the pro rata expense from Federal and State institutions.

Nearly 159,000 packages were dispatched during the year ended June 30, 1904, each of which was credited to the contributor and debited to the recipient. A recapitulation was also made, showing the aggregate contributions and receipts by each country. This necessary detail, in addition to the routine work of receiving and dispatching parcels, requires the continuous service of fifteen employees. The work requires the exclusive use of five rooms, which are arranged along the south basement of the Smithsonian building. These rooms, though originally remodeled and arranged expressly for the exchange service, have since been enlarged to some extent, but at times, when exchanges are received in unusual quantities, it is necessary temporarily to occupy adjoining rooms and hallways.

Aside from packing materials the supplies required are those necessary to a well-regulated office and for the greater part are procured under annual Government contracts.

Two instances have been reported during the year of loss or damage to exchange parcels in transit. One case, No. 414, for China, was subjected to the process of "general average" on account of damage to the steamship *St. Bede*, but a full report has not yet been submitted.

A case containing United States Government documents (designated as No. 90 of the official set), destined for the Parliamentary Library, Hobart, Tasmania, was destroyed while en route from London to Hobart, but most of the publications were fortunately duplicated.

The following tables describe the operations of the service during the year, and in comparison with the preceding year show a gain of 8,766 packages, or a total of 158,983, being an increase of 6,183 in the number sent abroad and an increase of 2,583 received from other countries. On the other hand, the total weight of exchanges

transmitted was less by 14 per cent. This inconsistency in figures was due to a preponderance of unusually large packages forwarded abroad during the year ended June 30, 1903, but the greater number of parcels during the last year shows an increased interest in the service and has resulted in adding several thousand names to the list of correspondents.

It is gratifying to note that of the weight of exchanges handled during the year ended June 30, 1904, 75 per cent was from domestic sources and 25 per cent from abroad, while during the previous year the proportions were 73.8 per cent and 26.2 per cent, respectively.

In July, 1897, an exchange list of foreign institutions was published which contained 9,414 addresses. The necessity for a revised list arising, a new edition was published in September, 1903, containing 12,720 addresses. This list, printed in limited edition at the expense of the Smithsonian Institution, is intended as a working guide for the United States International Exchange Service and its distributing agencies throughout the world, rather than for general distribution.

Tabular statement of the work of the International Exchange Service during the fiscal year 1903–1904.

Date.	Number of packages handled.	Weight of packages handled.	Number of correspondents June 30, 1904. Foreign societies.	Domestic societies.	Foreign individuals.	Domestic individuals.	Packages sent to domestic addresses.	Cases shipped abroad.
1903.								
July	17,725	41,063						
August	10,637	34,618						
September	10,548	26,236						
October	10,216	27,575						
November	15,645	63,253						
December	7,669	24,923						
1904.								
January	13,989	39,761						
February	14,969	56,962						
March	12,317	33,769						
April	16,288	34,413						
May	12,911	48,351						
June	16,069	50,486						
Total	158,983	481,410	13,257	3,464	24,901	6,450	38,702	1,987
Increase over 1902–1903	8,766	[a]78,308	136	145	3,569	210	4,722	[a]474

[a] Decrease.

The following table shows the number of packages of exchanges handled and the increase in the number of correspondents each year from 1897 to 1904:

	1897–98.	1898–99.	1899–1900.	1900–1901.	1901–1902.	1902–1903.	1903–1904.
Number of packages received	84,208	97,835	113,563	121,060	125,796	150,217	158,983
Weight of packages received, pounds	301,472	317,883	409,991	414,277	396,418	559,718	481,410
Correspondents:							
Foreign societies	10,165	10,322	10,845	11,295	11,760	13,121	13,257
Foreign individuals	12,378	13,378	15,385	16,261	17,701	21,332	24,901
Domestic societies	2,533	2,596	2,721	2,996	3,182	3,319	3,464
Domestic individuals	4,382	4,673	5,000	5,153	5,557	6,240	6,450
Packages to domestic addresses	21,057	30,645	28,625	31,367	33,961	33,980	38,702
Cases shipped abroad	1,330	1,500	1,768	1,757	1,847	2,461	1,987

CORRESPONDENTS.

The number of correspondents has increased to the extent of 4,060 during the year, and now aggregates 48,072. Of this number 16,721 are classified as institutions and 31,351 as individuals. In the United States the patrons of the service consist of 3,464 institutions and 6,450 individuals.

Number of correspondents of the International Exchange Service in each country on June 30, 1904.

Country.	Correspondents. Libraries.	Individuals.	Total.
AFRICA.			
Algeria	26	38	64
Angola	1	....	1
Azores	6	16	22
Beira	....	1	1
British Central Africa	1	3	4
British East Africa	....	2	2
Canary Islands	2	6	8
Cape Colony	58	101	159
Cape Verde Islands	....	5	5
Egypt	39	83	122
French Kongo	....	1	1
Gambia	....	2	2
German East Africa	3	....	3
Gold Coast	1	4	5
Kongo	....	5	5
Lagos	2	3	5
Liberia	3	10	13
Lourenço Marquez	....	2	2
Madagascar	5	9	14
Madeira	3	4	7
Mauritius	12	11	23
Morocco	....	10	10
Mozambique	....	1	1
Natal	21	24	45
Orange River Colony	1	3	4
Reunion	4	2	6
Rhodesia	6	8	14
St. Helena	3	2	5
Senegal	1	5	6
Sierra Leone	2	3	5
Transvaal	27	33	60
Tunis	7	9	16
Zanzibar	2	5	7
AMERICA (NORTH).			
Canada	337	575	912
Central America:			
British Honduras	5	14	19
Costa Rica	25	41	66
Guatemala	43	68	111
Honduras	13	39	52
Nicaragua	19	52	71
Salvador	20	13	33
Greenland	2	....	2
AMERICA (NORTH)—con.			
Mexico	169	228	397
Newfoundland	14	21	35
St. Pierre-Miquelon	2	2	4
United States	3,464	6,450	9,914
West Indies:			
Anguilla	....	1	1
Antigua	8	6	14
Bahamas	4	10	14
Barbados	10	25	35
Bermuda	6	22	28
Bonaire	....	1	1
Cuba	67	132	199
Curaçao	3	5	8
Dominica	2	7	9
Grenada	3	5	8
Gaudelope	2	6	8
Haiti	38	15	53
Jamaica	21	48	69
Martinique	....	3	3
Montserrat	....	2	2
Nevis	....	1	1
Porto Rico	8	34	42
St. Bartholomew	....	2	2
St. Christopher	2	7	9
St. Croix	1	4	5
St. Eustatius	....	2	2
St. Lucia	2	4	6
St. Martin	....	2	2
St. Thomas	2	6	8
St. Vincent	1	2	3
San Domingo	3	13	16
Tobago	....	2	2
Trinidad	16	13	29
Turk's Islands	3	6	9
AMERICA (SOUTH).			
Argentina	160	236	396
Bolivia	22	13	35
Brazil	150	180	330
British Guiana	19	15	34
Chile	88	110	198
Colombia	34	57	91
Dutch Guiana	5	4	9
Ecuador	21	26	47

Number of correspondents of the International Exchange Service in each country on June 30 1904—Continued.

Country.	Correspondents. Libraries.	Correspondents. Individuals.	Correspondents. Total.
AMERICA (SOUTH)—con.			
Falkland Islands	....	6	6
French Guiana	1	2	3
Panama	3	14	17
Paraguay	19	9	28
Peru	46	72	118
Uruguay	51	37	88
Venezuela	38	49	87
ASIA.			
Arabia	....	7	7
Beloochistan	....	1	1
Burma	11	9	20
Ceylon	26	19	45
China	48	117	165
Cyprus	3	4	7
Formosa	....	3	3
French India	1	1	2
Hongkong	11	30	41
India	237	250	487
Indo-China	8	7	15
Japan	171	448	619
Korea	2	13	15
Macao	1	1	2
Malaysia:			
Borneo	....	1	1
British New Guinea	....	1	1
British North Borneo	1	1	2
Celebes	....	4	4
Java	22	33	55
New Guinea	....	1	1
Philippine Islands	22	22	44
Sarawak	1	....	1
Sumatra	1	2	3
Persia	3	7	10
Portuguese India	1	....	1
Siam	6	21	27
Straits Settlements	15	20	35
AUSTRALASIA.			
New South Wales	85	172	257
New Zealand	91	137	228
Queensland	46	71	117
South Australia	44	77	121
Tasmania	23	31	54
AUSTRALASIA—con.			
Victoria	113	180	293
Western Australia	28	39	67
EUROPE.			
Austria-Hungary	767	1,387	2,154
Belgium	367	525	892
Bulgaria	14	16	30
EUROPE.			
Denmark	116	223	339
France	1,779	2,875	4,654
Germany	2,478	4,755	7,233
Gibraltar	1	5	6
Great Britain	2,113	6,025	8,138
Greece	41	53	94
Iceland	17	12	29
Italy	841	1,147	1,988
Luxemburg	13	5	18
Malta	12	15	27
Montenegro	2	1	3
Netherlands	213	372	585
Norway	142	215	357
Portugal	110	87	197
Roumania	38	64	102
Russia	537	1,076	1,613
Servia	22	15	37
Spain	206	251	457
Sweden	191	420	611
Switzerland	363	748	1,111
Turkey	40	94	134
POLYNESIA.			
Fiji Islands	1	9	10
German New Guinea	....	1	1
Guam	....	1	1
Hawaiian Islands	29	75	104
Marshall Islands	....	1	1
New Caledonia	....	2	2
New Hebrides	1	....	1
Samoa	....	5	5
Tahiti	....	8	8
Tonga	....	3	3
International	38	....	38
Total	16,721	31,351	48,072

EXCHANGE OF GOVERNMENT DOCUMENTS.

The following table represents the exchange transmissions for the several Departments and Bureaus of the Government during the year, showing a total of 16,235 packages received from abroad, and 74,863 packages sent to other countries, being an increase over the previous year of 29.5 per cent and 1.2 per cent, respectively.

Although still so far less than this Government's contributions, the receipts from abroad during the year show a substantial increase and it is believed mark the beginning of new activity on the part of other governments in reciprocating for the donations which have been made for so many years through the Smithsonian Institution.

Statement of Government exchanges during the year 1903–4.

Name of Bureau.	Packages. Received for—	Packages. Sent by—
American Historical Association	7	16
Astrophysical Observatory	11	....
Auditor for the State and other Departments	....	814
Board on Geographic Names	4	....
Bureau of American Ethnology	287	1,300
Bureau of American Republics	73	....
Bureau of the Census	63	863
Bureau of Education	119	1
Bureau of Fisheries	95	504
Bureau of Foreign Commerce	3	1
Bureau of Immigration	....	1
Bureau of Insular Affairs	....	2
Bureau of Labor	54	36
Bureau of Medicine and Surgery	3	....
Bureau of the Mint	5	369
Bureau of Navigation, Navy Department	7	....
Bureau of Navigation, Department of Commerce and Labor	....	38
Bureau of Public Health and Marine-Hospital Service	13	1,437
Bureau of Statistics, Department of Commerce and Labor	145	14,477
Civil Service Commission	11	6
Coast and Geodetic Survey	203	466
Commissioner of Internal Revenue	....	2
Commissioners of the District of Columbia	2	10
Comptroller of the Currency	35	180
Department of Agriculture	516	3,550
Department of Commerce and Labor	2	....
Department of the Interior	22	13
Department of Justice	1	....
Department of State	20	5
Engineer School of Application	2	....
Entomological Commission	2	....
General Land Office	4	....
Geological Survey	665	4,975
Health Department of the District of Columbia	1	....
House of Representatives	1	....
Hydrographic Office	99	....
Interstate Commerce Commission	25	276
Library of Congress	8,708	29,545
Life-Saving Service	1	46
Light-House Board	4	123
National Academy of Sciences	93	57
National Botanic Garden	1	....
National Bureau of Standards	3	....
National Museum	352	3,846
National Zoological Park	4	....
Nautical Almanac Office	27	98
Naval Observatory	152	521
Navy Department	17	....
Office of the Chief of Engineers	36	79
Office of Indian Affairs	4	....
Ordnance Office, War Department	3	....
Patent Office	334	1,257
President of the United States	1	....
Record and Pension Office	....	5
Senate of the United States	2	....
Smithsonian Institution	3,509	8,202
Superintendent of Documents	100	18
Surgeon-General's Office	165	302
Treasury Department	12	8
War Department	50	....
Weather Bureau	156	1,414
Total	16,234	74,863

RELATIVE INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

Following is a comparative statement of exchange transmissions between the United States and other countries during the years 1903 and 1904, respectively. Exchanges were conducted with 151 countries during the year ended June 30, 1904, or 16 more than during the preceding year. This demonstrates the constant growth of the service, extending even to remote parts of the world:

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1903, and June 30, 1904.

Country.	1903. Packages.		1904. Packages.	
	For—	From—	For—	From—
Algeria	176	70	131	65
Angola	5	....	3	....
Antigua	51	....	67	....
Arabia	26	....	39	....
Argentina	2,535	1,508	2,936	638
Austria-Hungary	5,667	3,719	5,349	2,969
Azores	34	....	46	....
Bahamas	42	....	43	....
Barbados	95	....	103	....
Belgium	2,728	2,790	2,848	2,459
Beloochistan	....	....	1	....
Bermudas	65	....	52	....
Bismarck Archipelago	....	....	1	....
Bolivia	125	14	127	32
Bonaire	....	....	1	....
Borneo	7	....	13	....
Brazil	2,305	1,430	2,228	847
British America	3,398	2,280	3,943	919
British Burma	1	....	....	....
British East Africa	....	....	9	....
British Central Africa	....	....	3	....
British Guiana	114	....	112	....
British Honduras	52	....	53	....
British West Africa	....	....	4	....
Bulgaria	133	....	168	....
Burma	3	....	13	....
Canary Islands	23	....	27	....
Cape Colony	873	....	542	228
Cape Verde Islands	....	....	6	....
Celebes	1	....	4	....
Ceylon	112	1	123	....
Chile	1,520	76	1,736	54
China	546	77	540	221
Colombia	733	....	872	....
Costa Rica	1,129	340	1,255	....
Cuba	565	596	1,012	97
Curaçao	27	....	22	....
Cyprus	9	....	5	....
Denmark	1,319	165	1,319	766
Dominica	12	....	75	....
Dutch Guiana	16	....	49	....
Dutch West Indies	....	....	1	....
Ecuador	646	6	165	....

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1903, and June 30, 1904—Con.

Country.	1903.		1904.	
	Packages.		Packages.	
	For—	From—	For—	From—
Egypt	286		252	2
Falkland Islands	12		13	
Fiji Islands	3		21	
Formosa	6			
France	10,670	4,687	9,764	5,032
French Cochin China	7			
French West Africa			2	
Gambia			2	
German East Africa	8		8	
Germany	17,581	6,085	17,621	6,928
Gibraltar	20		16	
Gold Coast	7		3	
Goree Dakar	22		16	
Grenada	13		8	
Great Britain and Ireland	18,038	7,106	17,696	8,383
Greece	683		811	4
Greenland	5		4	
Guadeloupe	13		19	
Guam			1	
Guatemala	233		230	
Haiti	503		635	
Hawaiian Islands	114		96	
Honduras	142	11	302	
Hongkong	127		135	
Iceland	55	1	48	
India	1,815	326	1,844	182
Italy	5,795	1,395	5,700	1,405
Jamaica	246		266	
Japan	2,245	12	2,463	18
Java	229	81	248	48
Kongo Free State	4			
Korea	61		67	
Lagos	3		2	
Leeward Islands			4	
Liberia	66		63	
Lourenço Marquez	13		19	
Luxemburg	95		88	1
Madagascar	38		24	
Madeira	18		22	
Malta	67		50	
Marshall Islands			6	
Martinique	4		9	
Mauritius	76		75	47
Mexico	2,127	3,466	2,279	1,619
Montenegro			1	
Montserrat			4	
Morocco	13		25	
Natal	157	30	133	95
Netherlands	2,479	1,100	2,495	778
New Caledonia			7	
Newfoundland	45		133	
New South Wales	2,021	363	2,109	375
New Zealand	871	6	975	4

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1903, and June 30, 1904—Con.

Country.	1903. Packages. For—	1903. Packages. From—	1904. Packages. For—	1904. Packages. From—
Nicaragua	138	....	239	....
Norway	1,459	940	1,495	663
Orange River Colony	5	....	11	....
Panama	....	....	24	....
Paraguay	98	47	178	....
Persia	59	....	51	....
Peru	752	1	992	224
Philippine Islands	56	....	86	2
Porto Rico	21	....	18	....
Portugal	947	38	1,058	337
Queensland	900	3	979	260
Reunion	16	....	14	....
Rhodesia	36	....	20	20
Roumania	261	59	335	1,233
Russia	4,606	849	4,699	2,346
St. Bartholomew	....	....	6	....
St. Croix	5	....	11	....
St. Eustatius	....	....	4	....
St. Helena	29	....	22	....
St. Kitts	9	....	21	....
St. Martin	12	....	16	....
St. Pierre and Miquelon	2	....	17	....
St. Thomas	14	....	14	....
St. Vincent	4	....	5	....
Samoa	17	....	25	....
Samos	6	....	2	....
San Salvador	134	....	152	8
Santa Lucia	19	....	13	....
Santo Domingo	33	....	3	....
Servia	71	....	78	....
Siam	84	....	195	110
Sierra Leone	13	....	18	....
Society Islands	12	....	20	....
South Australia	1,143	....	2,376	4
Spain	1,525	42	1,655	110
Straits Settlements	109	11	202	....
Sumatra	2	....	5	....
Sweden	2,205	374	2,123	928
Switzerland	2,757	829	2,762	1,359
Syria	48	....	115	....
Tasmania	569	6	790	24
Tonga	11	....	1	....
Tonquin	1	....	....	....
Transvaal	568	11	703	....
Trinidad	109	....	83	....
Tunis	55	....	38	....
Turkey	957	....	825	....
Turks Islands	27	....	25	....
United States	33,980	107,661	38,702	116,087
Uruguay	866	80	1,304	21
Venezuela	654	1	846	....
Victoria	1,786	1,145	1,920	816
Western Australia	619	112	813	214
Windward Islands	....	....	3	....
Zanzibar	17	....	21	....

In the main the same arrangements for distributing exchanges in other countries have continued during the year as have existed in the past. But one change requires special notice. I refer to the death at Leipzig-Gohlis, on February 6, 1904, of Dr. Carl Felix Alfred Flügel, in his eighty-fourth year.

Doctor Flügel succeeded his father in 1855 as agent of the Smithsonian Institution for the kingdoms and principalities which now constitute the German Empire, and continued in that capacity until his death, a continuous service of forty-nine years.

His long term of office gave Doctor Flügel an exceptional opportunity to further the work of the International Exchange Service throughout central Europe, of which he never failed to take advantage.

Doctor Flügel published numerous pamphlets and critical essays on the English language, and was the author of the standard work extensively known as Flügel's Dictionary of the English and German languages, which reached its fifteenth edition in 1891. The Institution deeply regrets his loss.

Mr. W. Irving Adams, chief clerk of the International Exchange Service, was in Leipzig on official business at the time of the death of Doctor Flügel and took immediate steps to recommend the selection of his successor in order that the work of the agency should suffer as little inconvenience as possible. The long and faithful service, the scholarly attainments, and wide acquaintance of Doctor Flügel made the selection of a suitable person a not inconsiderable task; but after careful inquiry Mr. Adams selected Mr. Karl W. Hiersemann, the bookseller of Leipzig, as Doctor Flügel's successor, and on March 8, 1904, the Secretary approved the selection by tendering Mr. Hiersemann the appointment. The central location of Mr. Hiersemann's establishment and his efficient clerical staff have already shown the selection to have been a fortunate one.

The progress of diplomatic negotiations between the United States and China with a view of establishing mutual exchange relations have frequently been referred to in the annual reports of the Exchange Service, and I am now pleased to announce that the matter has been referred by the Chinese department of foreign affairs to the superintendent of trade for the south (Nanking viceroy), with authority to deal with it. It would therefore seem that official exchange relations with China more nearly approach consummation than ever before. Meanwhile only occasional publications are received from China by mail, and no provision exists for sending exchanges from the United States to China except to addresses in Shanghai.

The indirect method of forwarding parcels to the West Indies through the Crown agents for the colonies in London has been abolished, and the services of colonial officers and educational institutions in several of the islands have been enlisted instead. In the near future it is hoped that similar arrangements will be perfected with other British colonies.

The department of foreign affairs, Bangkok, Siam, has accepted the invitation of the Institution to enter into a mutual arrangement for an exchange of publications, both governmental and scientific.

Following is a list of correspondents abroad through which the distribution of exchanges is accomplished. Those in the larger and in many of the smaller countries forward to the Smithsonian Institution reciprocal contributions for distribution in the United States.

Algeria (via France).
Angola (via Portugal).
Argentina: Museo Nacional, Buenos Ayres.
Austria: K. K. Statistische Central-Commission, Vienna.
Azores (via Portugal).
Belgium: Service Belge des Échanges Internationaux, Brussels.
Bolivia: Oficina Nacional de Inmigracion, Estadística y Propaganda Geográfica, La Paz.

Brazil: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
British Colonies: Crown Agents for the Colonies, London.[a]
Bulgaria: Dr. Paul Leverkühn, Sofia.
Canada: Sent by mail.
Canary Islands (via Spain).
Cape Colony: Superintendent of the Government Stationery Office, Cape Town.
Chile: Universidad de Chile, Santiago.
China: Shipments temporarily suspended.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Biblioteca Nacional, Quito.
East India: India Store Department, India Office, London.
Egypt: Société Khédiviale de Géographie, Cairo.
France: Bureau Français des Échanges Internationaux, Paris.
Friendly Islands: Sent by mail.
Germany: Karl W. Hiersemann, Königsstrasse 3, Leipzig.
Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex street, Strand, London.
Greece: Director of the American School of Classical Studies, Athens.
Greenland (via Denmark).
Guadeloupe (via France).
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea (via Portugal).
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Joseph von Körösy, "Redoute," Budapest.
Iceland (via Denmark).
Italy: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
Jamaica: Institute of Jamaica, Kingston.
Java (via Netherlands).
Liberia: Care of American Colonization Society, Washington, D. C.
Luxemburg (via Germany).
Madagascar (via France).
Madeira (via Portugal).
Mexico: Sent by mail.
Mozambique (via Portugal).
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.
New Guinea (via Netherlands).
New Hebrides: Sent by mail.
Newfoundland: Sent by mail.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
Paraguay: Ministerio de Relaciones Exteriores, Asuncion.
Persia (via Russia).

[a] This method is employed for communicating with a large number of the British colonies with which no means is available for forwarding exchanges direct.

Peru: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Exchange Board, Parliament House, Brisbane.
Roumania (via Germany).
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Salvador: Museo Nacional, San Salvador.
Santo Domingo: Sent by mail.
Servia (via Germany).
Siam: Minister for Foreign Affairs, Bangkok.
South Australia: Astronomical Observatory, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca Genesal del Ministerio de Instruccion Publica y Bellas Artes, Madrid.
Sumatra (via Netherlands).
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Tasmania: Royal Society of Tasmania, Hobart.
Tunis (via France).
Turkey: American Board of Commissioners for Foreign Missions, Boston.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library, Museums, and National Gallery, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Zanzibar: Sent by mail.

Save in a few instances, in which the mails were employed, parcels sent to foreign countries during the year were packed in boxes and were forwarded by express or freight. Of the 1,987 boxes of publications thus sent, 300 contained complete series of official documents of the United States for designated depositories, and 1,687 boxes contained United States departmental reports and scientific exchanges for miscellaneous addresses. The number of boxes of miscellaneous exchanges sent to each country is given below:

Argentina	35	Denmark	21
Austria	67	Dutch Guiana	([b])
Barbadoes	1	East Indies	21
Belgium	51	Egypt	3
Bermuda	1	France and colonies	191
Bolivia	4	Germany	277
Brazil	26	Great Britain and Ireland	341
British colonies	22	Greece	6
British Guiana	3	Guatemala	5
British Honduras	1	Honduras	5
Cape Colony	20	Hungary	26
China	3	Italy	78
Chile	21	Jamaica	3
Colombia	6	Japan	38
Costa Rica	8	Liberia	2
Cuba	([a])	Mexico	([a])

[a] Packages sent by mail. [b] Included in transmissions to Netherlands.

Natal	([a])	Servia	([c])
New South Wales	27	Siam	2
Netherlands	37	South Australia	11
New Providence	1	Spain	18
New Zealand	10	Sweden	42
Nicaragua	5	Switzerland	43
Norway	22	Syria	1
Paraguay	6	Tasmania	6
Peru	11	Transvaal	([a])
Polynesia	([b])	Trinidad	2
Portugal	12	Turkey	2
Queensland	12	Uruguay	10
Roumania	([c])	Venezuela	5
Russia	78	Victoria	19
Salvador	4	Western Australia	15

During the year six consignments of United States Government official publications were made to each of the fifty depositories for which provision was made under the joint resolution of Congress approved March 2, 1867. The transmissions were made to each depository on July 20 and November 20, 1903, and on January 11, February 17, April 15, and June 6, 1904. A list of these depositories follows:

Argentina: Library of the Foreign Office, Buenos Ayres.
Argentina: Biblioteca Pública Provincial, La Plata.
Australia: Commonwealth of Australia, Melbourne.
Austria: K. K. Statistische Central-Commission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Canada: Parliamentary Library, Ottawa.
Chile: Biblioteca del Congreso, Santiago.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba: Department of State, Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
England: School of Economics and Political Sciences, London.
France: Bibliothèque Nationale, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Secretary to the Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Foreign Office, Tokyo.
Mexico: Instituto Bibliográfico, Museo Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.

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[a] Included in transmissions to Great Britain.
[b] Packages sent by mail.
[c] Included in transmissions to Germany.

Ontario: Legislative Library, Toronto.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Quebec: Legislative Library, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Bibliothek, Dresden.
South Australia: Parliamentary Library, Adelaide.
Spain: Seccion de Propiedad Intelectual del Ministerio de Fomento, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: Government Library, Pretoria.
Turkey: Minister of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Württemberg: Königliche Bibliothek, Stuttgart.

The fifty sets of United States official publications referred to were delivered to the Smithsonian Institution from time to time as they came from press, and when a sufficient number was received to completely fill the boxes prepared for them, a list was printed to accompany each set, which was then shipped to its respective destination.

In addition to the above, either full or partial sets were provided under the joint resolution of Congress approved March 2, 1901, for the purpose of increasing exchanges with countries for which no provision was made under the limited resolution of March 2, 1867. The new depositories which had been designated to the close of the fiscal year 1903–4 were as follows:

Austria-Hungary: Bürgermeister der Haupt- und Residenz-Stadt, Vienna.
British Columbia: Legislative Assembly, Victoria.
Bulgaria: Minister of Foreign Affairs, Sophia.
Cape Colony: Superintendent of the Government Stationery Office, Cape Town.
France: Préfecture de la Seine, Paris.
Germany: Grossherzogliche Hof-Bibliothek, Darmstadt.
Germany: Senatskommission für die Reichs- und auswärtigen Angelegenheiten, Hamburg.
Germany: Foreign Office, Bremen.
Guatemala: Secretary of the Government, Guatemala.
Honduras: Secretary of the Government, Tegucigalpa.
Jamaica: Colonial Secretary, Kingston.
Manitoba: Provincial Library, Winnipeg.
Newfoundland: Colonial Secretary, St. Johns.
New Brunswick: Legislative Library, Fredericton.
Natal: Colonial Governor, Pietermaritzburg.
Nova Scotia: Legislative Library, Halifax.
Northwest Territories: Government Library, Regina.
Prince Edward Island: Legislative Library, Georgetown.
Paraguay: Oficina General de Informaciones y Canjes y Commisaria General de Inmigracion, Asuncion.
Roumania: Academia Romana, Bukharest.
Straits Settlements: Colonial Secretary, Singapore.
Siam: Foreign Office, Bangkok.

As new countries are constantly being added, the sets for the depositories designated under the last resolution are not forwarded simultaneously with those originally provided, but are delivered to the Institution from the Library of Congress and are dispatched with the next succeeding consignments of miscellaneous exchanges.

Messrs. William Wesley & Son and Dr. Joseph von Körösy continue to represent the Institution in Great Britain and Hungary, respectively, but, as above mentioned, a new agent, in the person of Mr. Karl W. Hiersemann, has been appointed to succeed the late Doctor Flügel in Germany. To these gentlemen, who are compensated by the Institution for their services, to the many individuals and institutions who render valuable aid in the promotion of the exchange service at large, and to Mr. Charles A. King, deputy collector of the port of New York, the grateful acknowledgments of the Smithsonian Institution are due.

Mr. W. Irving Adams, chief clerk of the International Exchange Service, returned on May 30, 1904, from a journey to Europe, undertaken for the purpose of promoting the interest of the service. It gives me pleasure to say that his observations will result in enlarging the scope of the Exchange Service and in inaugurating many improvements.

Permit me to commend the efficient manner in which the work of the Exchanges has been conducted by the office force under the immediate supervision of Mr. Adams, and, in his absence, under Mr. F. V. Berry. The increased work of the service, brought about by its growing usefulness, has sometimes been almost overwhelming, nevertheless there has been no undue delay in the transmission and distribution of the many thousands of packages handled and recorded during the year.

Respectfully submitted.

F. W. Hodge,
Acting Curator of Exchanges.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.
July 1, 1904.

Appendix IV.

REPORT OF THE SUPERINTENDENT OF THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to herewith submit the following report relating to the condition and operations of the National Zoological Park for the year ending June 30, 1904.

At the close of that period the approximate value of the property belonging to the park was as follows:

Buildings for animals	$100,000
Buildings for administrative purposes	14,000
Office furniture, books, apparatus, etc	4,200
Machinery, tools, and implements	2,200
Fences and outdoor inclosures	33,000
Roadways, bridges, paths, rustic seats, etc	80,000
Nurseries	1,000
Horses	400
Animals in zoological collection	42,000

A detailed list of the animals in the collection is appended hereto. They may be classified as follows:

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	318	154	69	541
Birds	290	127	28	445
Reptiles	113	12		125
Total	721	293	97	1,111

The accessions of animals during the year have been as follows:

Presented	93
Purchased and collected	251
Lent	19
Received from Yellowstone National Park	4
Received in exchange	6
Born in National Zoological Park	97
Total	470

The cost for purchase, collection, and transportation of these accessions has been $4,500.

The appropriation for the general service of the park was made in the following terms:

"For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety-five thousand dollars."

For some years past the want of sufficient accommodations for the animals at the park has been severely felt. This need seemed during the past season so urgent that all other objects not imperatively necessary for the maintenance of the collection were deferred, and the available resources were applied to the erection of a new house for mammals.

After consultation with Mr. F. L. Olmsted a site for the structure was selected near the principal animal house, in the situation shown in the accompanying plat (Pl. I). It was decided to build it of stone, using the same gray gneiss, found in the region of Rock Creek, that was used in building the principal house. A plan of the main floor of the structure is shown herewith (Pl. II). Its dimensions are as follows:

	Inside.	Outside.
	Ft. in.	*Ft. in.*
Length of rectangle	120 4	124 4
Width of rectangle	48 6	52 6
Extreme length	135 7	139 7
Extreme width	60 6	64 6

On reference to the accompanying plan it will be seen that the cages for the animals are arranged so as to be accessible from both front and rear. Small movable passageways will connect these inner cages with those to be constructed about the exterior of the building, stretching in each case across the service passage in the rear. The building will be lighted almost wholly by skylights, situated over the cages, so that the animals are in full light while the public is in comparative obscurity.

A contract was made for the walls of this building February 5, 1904. These walls were completed June 15, 1904, at a cost of $6,573. Other contracts have been made as follows:

For the structural ironwork	$7, 662
For the tile roof	4, 495

It is hoped that the iron work will be completed by October 31, 1904, and the tiling about a month later.

It is estimated that the total cost of the building will be about $40,000.

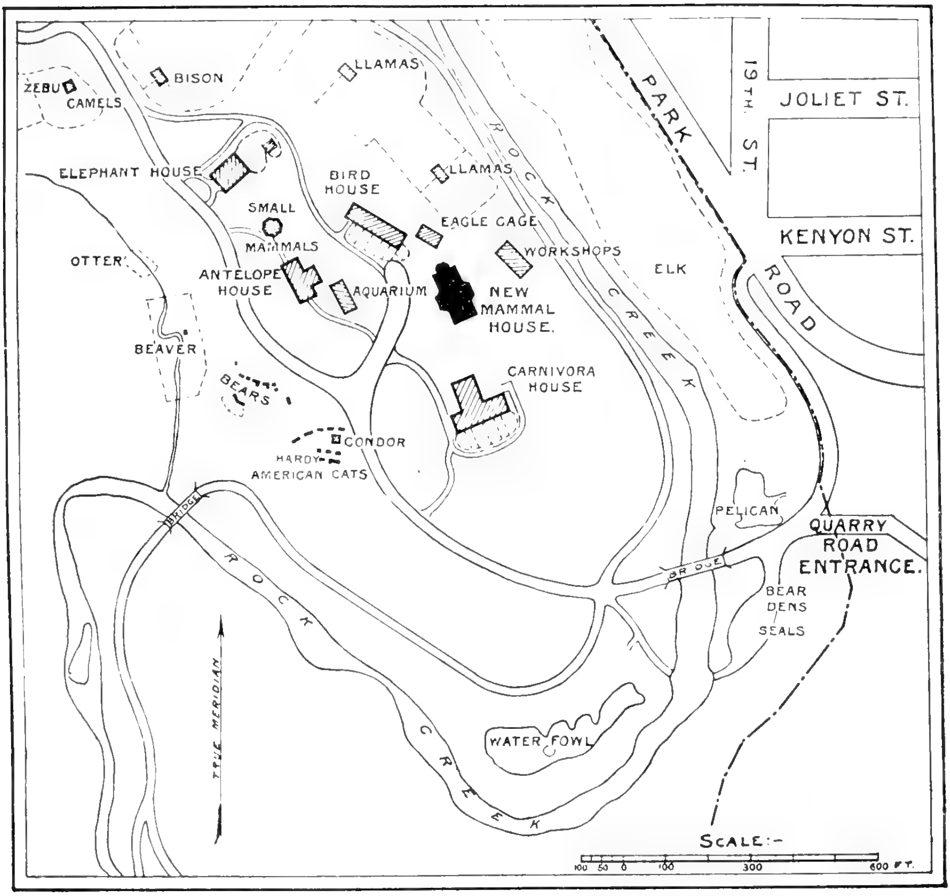
Fitting up old elephant house.—To supply temporarily the accommodations so badly needed for small mammals, the barn formerly occupied by the elephant was repaired and fitted up for this class of animals. It furnishes 23 cages. This cost $500.

New boiler in antelope house.—The heating boiler in the antelope house was one which had previously served for some years in the Smithsonian Institution building. At the close of the winter of 1902–3 it was found to be so badly corroded that it could no longer be used. A new vertical boiler was put in at a cost of $250.

New inclosure for buffaloes.—The buffalo paddocks on the steep northeastern slope of the narrow valley of Rock Creek were not sanitary. As a herd from Messrs. Cody and Bailey was accepted on deposit, it was necessary to construct a new inclosure on the hill near the Connecticut Avenue entrance. This was fenced with the posts and woven-wire fencing from the old paddocks, the cost of the paddock and shelter being $500.

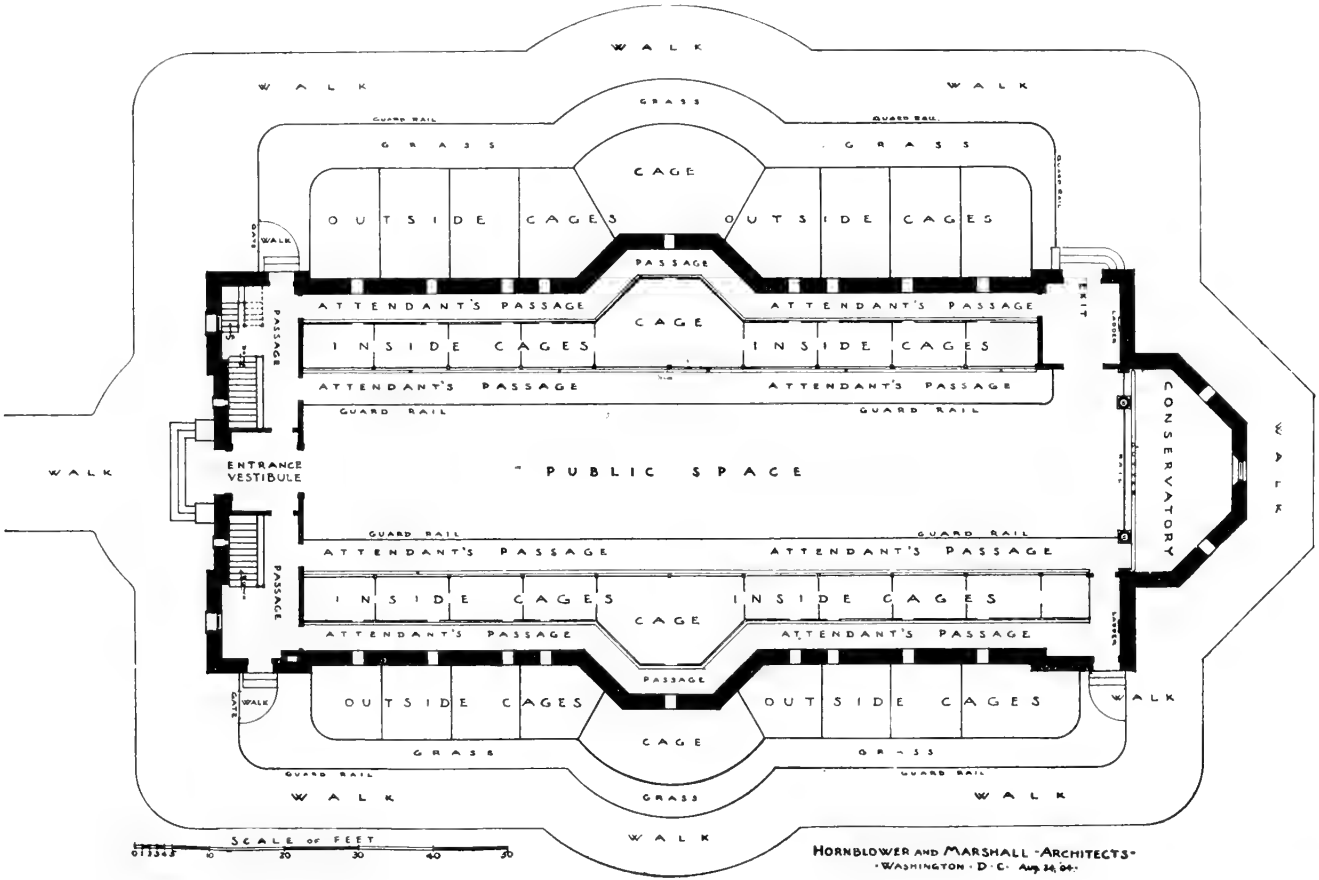
New raccoon tree.—The large tulip poplar, which had been occupied by the raccoons for a number of years, finally died. It was not in good condition when the park was established, and a heavy fill of earth had been made over its roots. To replace this a large oak was moved during the winter, and a new fence was built. This cost $500.

Repair and alteration of Adams Mill road.—The portion of Adams Mill road from the foot of the hill to the log bridge was in bad shape from irregular settling. During



LOCATION OF ANIMAL QUARTERS IN THE NATIONAL ZOOLOGICAL PARK.

New mammal house indicated in solid black.



PLAN OF MAIN FLOOR OF NEW HOUSE FOR ANIMALS, NATIONAL ZOOLOGICAL PARK.

the summer of 1903 the crown was reformed and a new surface dressing of crushed limestone was put on at a cost of $450. (This section of road is still in almost perfect condition, a good example of the ease with which a comparatively level road can be kept in repair as against one on a steep grade.)

This road was also widened at the entrance and reshaped to conform to the new lines of the highway approach outside. Cost, $250.

Repairing log bridge.—It was found that the floods in the creek had cut into and undermined the north abutment of this bridge, and additional concrete was put in and faced with stone slabs. The trend of the current against the abutment was prevented for the future by removing a gravel bank and burying a few logs in the edge of the stream to turn the water toward the center and prevent scouring. Cost, $250.

Water supply from the main on Connecticut avenue extended.—The water supply for the entire park had been furnished by a 6-inch main, laid at the expense of the park, down Quarry road from Columbia road. The supply in the higher parts of the park, on the west side, was not satisfactory, and it was impossible to maintain sufficient pressure when water was being used in the lower levels. A new pipe to supply the western part of the park was laid from the main on Connecticut avenue extended, at a cost of $250.

Bookcases for office.—Reference books and bookcases for the superintendent's office were purchased during the year at a cost of $200.

Noteworthy accessions.—A young male lion, presented to the President by King Menelik, of Abyssinia, was deposited in the park by the President. A spotted hyena, presented by N. E. Skinner, special envoy to King Menelik. Twelve American bison were loaned by Messrs. Bailey and Cody. One phalanger and 2 bridled wallabies were received from Dr. F. W. Goding, United States consul at Newcastle, New South Wales. Four coyotes were presented by Major Pitcher, acting superintendent, Yellowstone National Park. Nine wandering tree ducks were presented by Carl Hagenbeck. One Himalayan bear was received from the New York Zoological Park in exchange.

Purchases.—A Kodiak bear. (This species is the largest carnivorous land animal now in existence; one killed at English Bay, Kodiak Island, weighed 1,756 pounds.) In this connection it is of interest to note that the male of *Ursus dalli gyas*, now in the park, which weighed in June, 1903, 450 pounds, had attained a weight, January 18, 1904, of 625 pounds. A Mexican mountain sheep. A pair of yearling moose obtained in Manitoba. A pair of jaguars. A male Bactrian camel, procured as a mate for the female already in the collection. A California condor. A female black bear, from the Province of Quebec; an unusually fine specimen, weighing 380 pounds.

Births.—Eight wild turkeys hatched in the park. Brown pelican, sandhill crane, and Canada goose also nested, and the emu laid two eggs.

Important losses.—Two American bison, gastro-enteritis. One pair moose. One American antelope. Mule deer—3 from disease, 2 from fright by buffalo, 1 female killed by a male. Two jaguars—intense catarrhal inflammation throughout intestinal tract; virulent colon germs found, pathogenic to rabbits and guinea pigs. One puma. Black bear—pneumonia, 2; gastro-enteritis from *Ascaris transfuga*, 2. One grizzly bear, gastro-enteritis with nephritis; in the collection since June, 1888. One sun bear, from gastro-enteritis. One Japanese bear, shock from cutting claws. Four Arctic foxes, no intestinal worms found; they were found in subsequent cases. Two European flamingoes, *Tropidocerca* (a nematode worm found in subsequent cases) producing fatal inflammation of the digestive tract. One cassowary from serous pericarditis.

A considerable number of monkeys, birds (parrots, etc.), and snakes died from results of overcrowding or lack of proper quarters.

The post-mortem examinations were made by the Bureau of Animal Industry, to whose courtesy the thanks of the park are due.

Exchange with New Zealand government.—The New Zealand government arranged, through the President, to obtain elk from the herd in the National Zoological Park in exchange for other animals. Ten elk are to be sent, and will be forwarded in the autumn of 1904, after the horns are hard and the young have been weaned.

Readjustment of boundaries.—The desirability of having the park bordered by highways along the eastern and western sides has been urged at various times and brought to the attention of Congress. A bill for the establishment of highways adjacent to the park was submitted by the Commissioners of the District of Columbia during the session of 1903–4, and passed as given below:

"AN ACT For the opening of connecting highways on the east and west sides of the zoological park, District of Columbia.

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That within six months after the passage of this act the Commissioners of the District of Columbia be, and they are hereby, authorized and directed to institute in the supreme court of the District of Columbia, sitting as a district court, by petition, particularly describing the lands to be taken, a proceeding in rem to condemn the land that may be necessary for connecting the north end of Adams Mill road in Lanier Heights with south end of Park road in Ingleside by a highway fifty feet wide along or near the eastern boundary of the zoological park, also for connecting Cathedral avenue with Klingle road by a highway fifty feet wide along or near the western boundary of the zoological park, all in accordance with plans on file in the office of the Engineer Commissioner, District of Columbia." Public act, April 28, 1904.

The estimates for the park for the year 1904–5, as submitted to Congress, contained the following item:

"Readjustment of boundaries, National Zoological Park: Acquirement of the tract of land lying between the present eastern boundary of the National Zoological Park and the new highway to be established by the District of Columbia from Adams Mill road to Kenesaw avenue, and also of the tract lying between the present western boundary of said park and the new highway to be established by the District of Columbia from Cathedral avenue to Klingle road, sixty thousand dollars; and said land, when acquired, to become a part of the National Zoological Park."

Congress took no action upon this estimate.

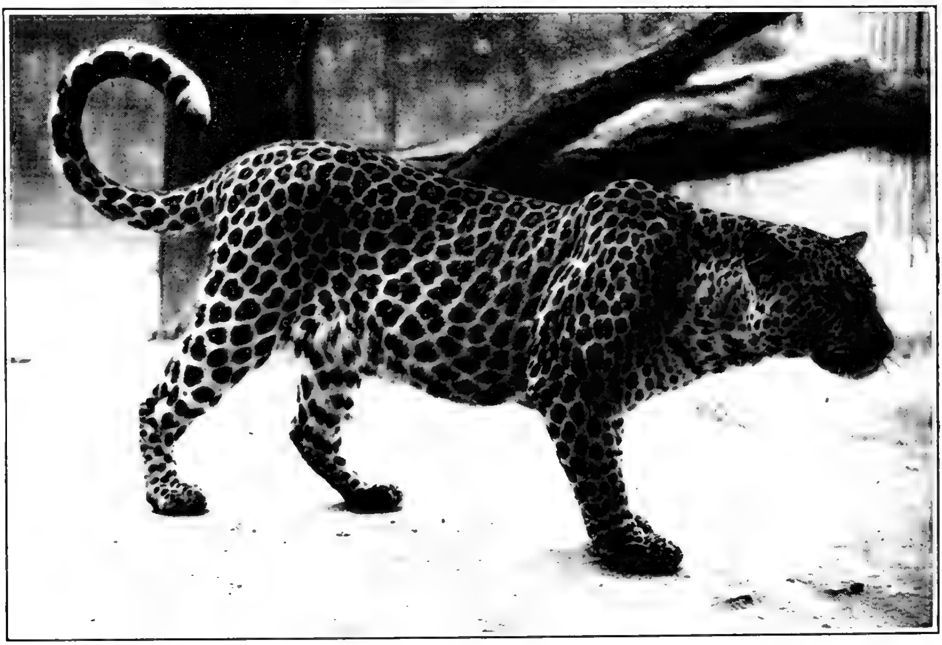
Exhibit at Louisiana Purchase Exposition.—In view of the importance of bringing before the general public the aims and objects of the park it was thought proper to prepare an exhibit of some extent for the Louisiana Purchase Exposition. This consisted of a display of living birds confined in a flying cage occupying a ground space of 84 by 228 feet, and from 50 to 55 feet in height. It was constructed by the St. Paul Foundry Company, according to plans prepared by the Supervising Architect of the Treasury Department after preliminary sketches furnished by the park. The cost of the cage was about $15,000. Its frame consists of light steel arches, covered by a wire netting with three-fourths-inch mesh. A longitudinal partition divides the cage into two parts, and a passage for the public 14 feet wide extends from end to end.

One side is occupied mainly by marsh and water birds and has two swimming pools, each from 50 to 60 feet long. The other side is occupied mainly by song birds and small species noted for bright plumage, and has two smaller pools with a streamlet of water trickling from one to the other, a distance of 90 feet, through a series of small, shallow basins that afford drinking and bathing places for the little birds. This side includes several moderate-sized growing trees which were left in their natural situation. Besides these, many small trees and shrubs were planted and the surface was sodded. The cage was located in a natural grove of trees not far from the Government building in the exposition grounds. All ground improvements, including water supply, etc., were furnished by the exposition company at its own expense.

The cost of stocking and maintaining the cage was defrayed from the Government

BIRD CAGE AT LOUISIANA PURCHASE EXPOSITION.

GREAT BROWN BEAR FROM PENINSULA OF ALASKA, IN NATIONAL ZOOLOGICAL PARK. AGE ABOUT 2½ YEARS.



LEOPARD IN NATIONAL ZOOLOGICAL PARK.

Presented by Mr. E. S. Cunningham, United States consul, Aden, Arabia.

exhibit fund. Birds were purchased from dealers and collectors, but, as it was desirable to have as many as possible already accustomed to such confinement, a considerable number were supplied from the stock in the National Zoological Park. A head keeper and one underkeeper were employed during the month of May and another underkeeper during June.

It is expected that at the close of the exposition the cage will be brought to Washington and ultimately erected in the National Zoological Park.

Animals in National Zoological Park June 30, 1904.

Name.	Number.
MAMMALS.	
North American species.	
American bison (*Bison americanus*)	15
Mexican mountain sheep (*Ovis mexicana*)	1
Prong-horn antelope (*Antilocapra americana*)	1
Virginia deer (*Odocoileus virginianus*)	12
Columbia black-tailed deer (*Odocoileus columbianus*)	1
Mule deer (*Odocoileus hemionus*)	8
American elk (*Cervus canadensis*)	36
Newfoundland caribou (*Rangifer terræ-novæ*)	1
Moose (*Alces americanus*)	2
Collared peccary (*Tayassu angulatum*)	1
Cougar (*Felis concolor*)	1
Oregon cougar (*Felis concolor oregonensis*)	1
Ocelot (*Felis pardalis*)	4
Cacomitl cat (*Felis cacomitli*)	2
Bay lynx (*Lynx rufus*)	2
Spotted lynx (*Lynx rufus maculatus*)	2
Florida lynx (*Lynx rufus floridanus*)	2
Canada lynx (*Lynx canadensis*)	1
Gray wolf (*Canis griseus*)	7
Black wolf (*Canis griseus*)	1
Coyote (*Canis latrans*)	8
Coyote (*Canis frustror*)	2
Red fox (*Vulpes fulvus*)	4
Cross fox (*Vulpes fulvus*)	1
Arctic fox (*Vulpes lagopus*)	36
Swift fox (*Vulpes velox*)	6
Gray fox (*Urocyon cinereoargenteus*)	4
North American otter (*Lutra hudsonica*)	2
Fisher (*Mustela pennantii*)	2
American badger (*Taxidea taxus*)	2
Kinkajou (*Totos caudivolvulus*)	3
American civet cat (*Bassariscus astutus*)	1
Raccoon (*Procyon lotor*)	10
Black bear (*Ursus americanus*)	8
Grizzly bear (*Ursus horribilis*)	3
Yakutat bear (*Ursus dalli*)	1
MAMMALS—continued.	
North American species—Continued.	
Alaska Peninsula brown bear (*Ursus dalli gyas*)	
Kodiak bear (*Ursus middendorffi*)	1
Polar bear (*Thalassarctos maritimus*)	2
California sea lion (*Zalophus californianus*)	1
Steller's sea lion (*Eumetopias stelleri*)	2
Harbor seal (*Phoca vitulina*)	4
Common pocket gopher (*Geomys bursarius*)	2
California pocket gopher (*Thomomys bottæ*)	2
American beaver (*Castor canadensis*)	11
Hutia-conga (*Capromys pilorides*)	12
Woodchuck (*Arctomys monax*)	2
Southern fox squirrel (*Sciurus niger*)	4
Western fox squirrel (*Sciurus ludovicianus*)	16
Gray squirrel (*Sciurus carolinensis*)	22
Black squirrel (*Sciurus carolinensis*)	9
Mountain chipmunk (*Tamias speciosus*)	18
Beechey's ground squirrel (*Spermophilus grammurus beecheyi*)	1
Antelope chipmunk (*Spermophilus leucurus*)	2
Mexican ground squirrel (*Spermophilus mexicanus*)	1
Northern varying hare (*Lepus americanus*)	9
Opossum (*Didelphys marsupialis*)	2
Domesticated and foreign species.	
Diana monkey (*Cercopithecus diana*)	1
Green monkey (*Cercopithecus callitichus*)	3
Sooty mangabey (*Cercocebus fuliginosus*)	2
Bonnet monkey (*Macacus sinicus*)	1
Macaque monkey (*Macacus cynomolgus*)	10
Pig-tailed monkey (*Macacus nemestrinus*)	4
Japanese monkey (*Macacus speciosus*)	1
Black ape (*Cynopithecus niger*)	3
Arabian baboon (*Papio hamadryas*)	1
Yellow baboon (*Papio babuin*)	3

Animals in National Zoological Park June 30, 1904—Continued.

Name.	Number.
MAMMALS—continued.	
Domesticated and foreign species—Con.	
Doguera baboon (*Papio doguera*)	2
Ruffed lemur (*Lemur varius*)	1
Lion (*Felis leo*)	8
Tiger (*Felis tigris*)	2
Leopard (*Felis pardalis*)	2
Serval (*Felis serval*)	3
Yaguarundi (*Felis yaguarundi*)	1
Caracal (*Lynx caracal*)	2
Spotted hyena (*Hyæna crocuta*)	2
Striped hyena (*Hyæna striata*)	2
Wolf hound	2
St. Bernard dog	1
Pointer	1
Bedlington terrier	1
Smooth-coated fox terrier	1
Wire-haired fox terrier	1
Dingo (*Canis dingo*)	1
Black-backed jackal (*Canis mesomelas*)	1
Palm civet (*Paradoxurus fasciatus*)	1
Mongoose (*Herpestes mungo*)	1
Tayra (*Galictis barbara*)	1
Red coatimundi (*Nasua rufa*)	1
Crab-eating raccoon (*Procyon cancrivora*)	1
Himalayan bear (*Ursus tibetanus*)	1
Sloth bear (*Melursus ursinus*)	2
Wild boar (*Sus scrofa*)	1
Solid-hoofed pig (*Sus scrofa*)	1
Zebu (*Bos indicus*)	7
Carabao (*Bos bubalus*)	1
Yak (*Poëphagus grunniens*)	2
Barbary sheep (*Ovis tragelaphus*)	7
Common goat (*Capra hircus*)	9
Angora goat (*Capra hircus*)	2
Nilgai (*Boselaphus tragocamelus*)	4
Indian antelope (*Antilope cervicapra*)	2
Sambur deer (*Cervus aristotelis*)	2
Axis deer (*Cervus axis*)	1
Red deer (*Cervus elaphus*)	1
Mexican deer (*Odocoileus mexicanus*)	1
Venezuelan deer (*Cariacus sp.*)	2
Fallow deer (*Dama vulgaris*)	7
Common camel (*Camelus dromedarius*)	2
Bactrian camel (*Camelus bactrianus*)	2
Llama (*Auchenia glama*)	1
South American tapir (*Tapirus americanus*)	3
Donkey (*Equus asinus*)	1
Indian elephant (*Elephas indicus*)	1
Ecuador squirrel (*Sciurus sp.*)	1
Mexican agouti (*Dasyprocta mexicana*)	1
Hairy-rumped agouti (*Dasyprocta prymnolopha*)	2
Azara's agouti (*Dasyprocta azaræ*)	2
Acouchy (*Dasyprocta acouchy*)	3
Golden agouti (*Dasyprocta aguti*)	3
Guinea pig (*Cavia porcellus*)	12
Albino rat (*Mus rattus*)	5
Coypu (*Myocastor coypus*)	5
Crested porcupine (*Hystrix cristata*)	2
Domestic rabbit (*Lepus cuniculus*)	16
Great gray kangaroo (*Macropus giganteus*)	2
Wallaroo (*Macropus robustus*)	1
Red kangaroo (*Macropus rufus*)	2
Black-striped wallaby (*Macropus dorsalis*)	1
Pademelon wallaby (*Macropus thetidis*)	4
Grey's wallaby (*Macropus greyi*)	1
Brush-tailed rock kangaroo (*Petrogale penicillata*)	5
Bridled wallaby (*Onychogal frenata*)	1
Rat-kangaroo (*Æpyrmnus rufescens*)	6
Flying phalanger (*Petaurus sciureus*)	1
Common phalanger (*Trichosurus vulpecula*)	4
Bandicoot (*Perameles sp.*)	1
Tasmanian wolf (*Thylacynus cynocephalus*)	3
Tasmanian devil (*Sarcophilus ursinus*)	1
Australian native cat (*Dasyurus sp.*)	2
Manicou (*Didelphys sp.*)	2
BIRDS.	
Mockingbird (*Mimus polyglottos*)	1
Strawberry finch (*Sporæginthus flaviventris*)	1
Painted grass-finch (*Poëphila mirabilis*)	3
Bar-breasted finch (*Munia nisoria*)	5
Java sparrow (*Padda oryzivora*)	5
Parson finch	1
Green jay (*Xanthoura luxuosa*)	4
Toucan (*Ramphastos tocard*)	1
Giant kingfisher (*Dacelo gigas*)	5
Sulphur-crested cockatoo (*Cacatua galerita*)	3
Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Bare-eyed cockatoo (*Cacatua gymnopis*)	1
Roseate cockatoo (*Cacatua roseicapilla*)	5
Yellow and blue macaw (*Ara ararauna*)	3
Red and yellow and blue macaw (*Ara macao*)	2
Red and blue macaw (*Ara chloroptera*)	2
Great green macaw (*Ara militaris*)	1
Chattering lory (*Lorius garrulus*)	1

Animals in National Zoological Park June 30, 1904—Continued.

Name.	Number.
BIRDS—continued.	
Green paroquet (*Conurus sp.*)	1
Carolina paroquet (*Conurus carolinensis*)	2
Yellow-naped amazon (*Amazona auropalliata*)	1
White-fronted amazon (*Amazona leucocephala*)	2
Orange-winged amazon (*Amazona amazonica*)	2
Yellow-shouldered amazon (*Amazona ochroptera*)	1
Rose-hill parrakeet (*Platycercus eximius*)	1
Grass parrakeet (*Melopsittacus undulatus*)	4
King parrakeet (*Aprosmictus cyanopygius*)	1
Cockateel (*Calopsittacus novæ-hollandiæ*)	3
Great horned owl (*Bubo virginianus*)	14
Barred owl (*Syrnium nebulosum*)	4
Barn owl (*Strix pratincola*)	3
Venezuelan owl	1
Screech owl (*Megascops asio*)	1
Sparrow hawk (*Falco sparverius*)	1
Bald eagle (*Haliæetus leucocephalus*)	13
Harpy eagle (*Thrasaëtus harpyia*)	1
Golden eagle (*Aquila chrysaëtos*)	5
Wedge-tailed eagle (*Uroaëtus audax*)	1
Crowned hawk-eagle (*Spizaëtus coronatus*)	1
Red-tailed hawk (*Buteo borealis*)	2
Venezuelan hawk	1
California condor (*Gymnogyps californianus*)	5
Turkey vulture (*Cathartes aura*)	6
Black vulture (*Catharista atrata*)	1
King vulture (*Gypagus papa*)	1
Lanzarotte pigeon (*Columba livia*)	1
Ring dove (*Columba palumbus*)	9
Bar-shouldered dove (*Geopelia humeralis*)	2
Bronze-winged pigeon (*Phaps chalcoptera*)	1
Crested pigeon (*Ocyphaps lophotes*)	1
Wild turkey (*Meleagris gallopavo ferus*)	11
Chachalaca (*Ortalis vetula maccallii*)	2
Daubenton's curassow (*Crax daubentoni*)	5
Lesser razor-billed curassow (*Mitua tomentosa*)	1
Peafowl (*Pavo cristatus*)	22
Sharp-tailed grouse (*Pediocætes phasianellus*)	1
Prairie hen (*Tympanuchus americanus*)	9
California partridge (*Callipepla californica*)	12
American coot (*Fulica americana*)	2
Purple gallinule (*Porphyrio cæruleus*)	1
Black-backed gallinule (*Porphyrio melanotus*)	2
Demoiselle crane (*Anthropoides virgo*)	3
Sandhill crane (*Grus mexicana*)	2
Whooping crane (*Grus americana*)	1
Thicknee (*Œdicnemus grallarius*)	2
Little blue heron (*Ardea cærulea*)	8
Great blue heron (*Ardea herodias*)	13
Louisiana heron (*Ardea tricolor ruficollis*)	7
Black-crowned night heron (*Nycticorax nycticorax nævius*)	25
Australian bittern	1
Boatbill (*Cochlearius cochlearius*)	1
White stork (*Ciconia alba*)	1
Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilus crumeniferus*)	1
Wood ibis (*Tantalus loculator*)	8
Glossy ibis (*Plegadis autumnalis*)	3
Sacred ibis (*Ibis æthiopica*)	4
White ibis (*Guara alba*)	25
Trumpeter swan (*Olor buccinator*)	5
Whistling swan (*Olor columbianus*)	2
Mute swan (*Cygnus gibbus*)	2
Black swan (*Cygnus atratus*)	2
Wandering tree-duck (*Dendrocygna arcuata*)	7
Australian tree-duck (*Dendrocygna eytoni*)	1
American tree-duck (*Dendrocygna discolor*)	1
Brant (*Branta bernicla*)	1
Canada goose (*Branta canadensis*)	7
Hutchins's goose (*Branta canadensis hutchinsii*)	1
Chinese goose (*Anser cygnoides*)	1
Greater snow goose (*Chen hyperborea nivalis*)	6
Muscovy duck (*Cairina moschata*)	3
Wood duck (*Aix sponsa*)	21
Mandarin duck (*Dendronessa galericulata*)	3
Pintail (*Dafila acuta*)	6
Blue-winged teal (*Anas discors*)	3
Green-winged teal (*Anas carolinensis*)	6
Black duck (*Anas obscura*)	1
Pekin duck (*Anas sp.*)	1
Common duck (*Anas boschas*)	3
Australian wild duck (*Anas superciliosa*)	1

Animals in National Zoological Park June 30, 1904—Continued.

Name.	Number.	Name.	Number.
BIRDS—continued.		REPTILES—continued.	
American flamingo (*Phœnicopterus ruber*)	4	Duncan Island tortoise (*Testudo ephippium*)	2
American white pelican (*Pelecanus erythrorhynchos*)	6	Albemarle Island tortoise (*Testudo vicina*)	2
European white pelican (*Pelecanus onocrotalus*)	2	Iguana (*Iguana tuberculata*)	1
Brown pelican (*Pelecanus fuscus*)	4	Comb lizard (*Ctenosaura sp.*)	1
Herring gull (*Larus argentatus*)	1	Chuckawalla (*Sauromalus ater*)	1
American herring gull (*Larus argentatus smithsonianus*)	3	Horned lizard (*Phrynosoma cornutum*)	7
Florida cormorant (*Phalacrocorax dilophus floridanus*)	14	Great Basin horned lizard (*Anota platyrhina*)	6
Snake bird (*Anhinga anhinga*)	6	Australian hooded lizard	1
Common rhea (*Rhea americana*)	1	Gila monster (*Heloderma suspectum*)	6
Cassowary (*Casuarius australis*)	2	Diamond rattlesnake (*Crotalus adamanteus*)	7
Emu (*Dromæus novæ-hollandiæ*)	3	Banded rattlesnake (*Crotalus horridus*)	3
REPTILES.		Prairie rattlesnake (*Crotalus confluentis*)	1
		California rattlesnake (*Crotalus lucifer*)	1
Alligator (*Alligator mississippiensis*)	14	Copperhead (*Ancistrodon contortrix*)	4
Rough-eyed caiman (*Caiman sclerops*)	1	Watermoccasin (*Ancistrodon piscivorus*)	1
American crocodile (*Crocodilus americanus*)	2	Indian python (*Python molurus*)	2
Painted turtle (*Chrysemys picta*)	6	Cuban tree boa (*Epicrates angulifer*)	3
Musk turtle (*Aromochelys odorata*)	2	Common boa (*Boa constrictor*)	1
Mud turtle (*Cinosternum pennsylvanicum*)	5	Anaconda (*Eunectes murinus*)	2
Terrapin (*Pseudemys sp.*)	1	Bull snake (*Pityophis sayi sayi*)	1
Gopher turtle (*Xerobates polyphemus*)	1	Pine snake (*Pityophis melanoleucus*)	5
Box tortoise (*Cistudo carolina*)	2	Black snake (*Bascanium constrictor*)	7
Three-toed box tortoise (*Cistudo triunguis*)	6	King snake (*Ophibolus getulus*)	3
Painted box tortoise (*Cistudo ornata*)	5	Milk snake (*Oscecola doliata triangula*)	1
		Garter snake (*Eutænia sirtalis*)	3
		Water snake (*Natrix sipedon*)	5
		Gopher snake (*Spilotes corais couperii*)	3

Animals presented during the fiscal year ending June 30, 1904.

Name.	Donor.	Number.
Green monkey	Miss Justine Ingersoll, New Haven, Conn	1
Do	Crew of U. S. S. Mayflower	1
Macaque monkey	Miss Justine Ingersoll, New Haven, Conn	2
White-throated capuchin	Mrs. Albert Clifford Barney, Washington, D. C.	2
Weeper capuchin	H. A. Howes, Washington, D. C	1
Lion	The President	1
Ocelot	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Bay lynx	The President	1
Spotted hyena	R. P. Skinner, special envoy to King Menelik of Abyssinia	1
Red fox	Chas. W. Beach, Berks, Va	1
Gray fox	A. B. Claxton, Washington, D. C.	1
Do	Harry A. Pond, Fayette, Iowa	1
Raccoon	J. W. Linton, Richmond, Va.	1
Do	J. L. Jasper, Washington, D. C.	1
Virginia deer	Mrs. Thomas Bushby, Takoma Park, Md	1
Venezuelan deer	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Fox squirrel	O. W. Underwood, Richmond, Va	1
Woodchuck	Joseph Sanders, Washington, D. C.	1

Animals presented during the fiscal year ending June 30, 1904—Continued.

Name.	Donor.	Number.
Canada porcupine	Jas. Holdcroft, Mayfield, Mich	1
Angora guinea pig	Chas. W. Stewart, Washington, D. C	1
English rabbit	J. S. Donaldson, Washington, D. C	2
Manicou	Miss Mary B. Thayer, Monadnock, N. H	2
Albino opossum	J. W. Oliver, Newport, Ark	1
Mocking bird	Mrs. C. E. Ferguson, Washington, D. C	1
American magpie	Jas. Fullerton, Red Lodge, Mont	2
White-fronted amazon	Capt. C. F. Shoemaker, Washington, D. C	1
Grass parrakeet	Dr. E. F. Smith, Washington, D. C	2
Parrakeet	Mrs. W. M. Black, Washington, D. C	1
Do	Horace Wylie, Washington, D. C	1
Great horned owl	H. W. Cheek, Washington, D. C	1
Do	J. P. McKallow, Chevy Chase, Md	1
Do	Wm. Beuchert, Washington, D. C	1
Short-eared owl	C. E. Mallory, Buffalo Center, Iowa	2
Barred owl	Sergeant Carroll, Washington, D. C	1
Do	Donor unknown	1
Barn owl	Geo. R. Moberly, Frederick, Md	1
Golden eagle	The President	1
Red-tailed hawk	E. Whitney, Washington, D. C	1
Venezuelan hawk	E. H. Plumacher, United States consul, Maracaibo, Venezuela	1
Daubenton's curassow	.....do	2
American bittern	C. E. Mallory, Buffalo Center, Iowa	2
Wandering tree duck	Carl Hagenbeck, Hamburg, Germany	9
Snake bird	A. M. Nicholson, Orlando, Fla	1
Alligator	D. Diggons, Washington, D. C	1
Do	J. Rochon, Washington, D. C	1
Rough-eyed caiman	E. H. Plumacher, United States consul, Maracaibo, Venezuela	2
Chuckawalla	Otto Holstein, Mellen, Ariz	3
Horned lizard	R. H. Fatt and Maj. D. B. Johnson, Washington, D. C	5
Glass snake	Miss Ethel Roosevelt	1
Banded rattlesnake	J. B. Dahlgren, Hancock, Md	1
Prairie rattlesnake	Jas. Fullerton, Red Lodge, Mont	2
Massasauga	Prof. Hubert Lyman Clark, Olivet, Mich	1
Copperhead	J. B. Dahlgren, Hancock, Md	5
Bull snake	James Fullerton, Red Lodge, Mont	2
Black snake	E. T. Carrico, Stithton, Ky	1
Do	Dr. L. Stejneger, Washington, D. C	1
Do	Prof. Hubert Lyman Clark, Olivet, Mich	3
Milk snake	J. Y. Detwiler, New Smyrna, Fla	1
Garter snake	E. T. Carrico, Stithton, Ky	1
Hog-nosed snake	.....do	1
"Congo snake"	Wm. P. Seal, Delair, N. J	1

SUMMARY.

	Number.
Animals on hand July 1, 1903	1,000
Accessions during the year	470
Total	1,470
Deduct loss (by exchange, death, and returning of animals)	359
On hand June 30, 1904	1,111

Respectfully submitted.

FRANK BAKER, *Superintendent.*

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Appendix V.

REPORT OF THE WORK OF THE ASTROPHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1904.

Sir: The kinds and amounts of Observatory property are approximately as follows:

Buildings	$6,300
Apparatus	41,400
Library and records	6,800
Total	54,500

During the past year the acquisitions of property have been as follows:

(a) *Apparatus.*—Astronomical and physical apparatus has been purchased at an expenditure of $4,500. The most important pieces comprise a new spectrobolometric outfit, to be used in the study of the great solar image of the 140-foot focus horizontal telescope, and also for a proposed expedition to some elevated station for the determination of the solar constant. Of the sum expended for apparatus, $2,430 was chargeable to the appropriations of 1901–2 and 1902–3. Shelters for the great horizontal telescope and apparatus for the research on the solar constant have been ordered, at an estimated expenditure of $1,230. A ground plan of the Observatory enclosure, including the new shelters, is shown in Plate V.

(b) *Library and records.*—The usual periodicals have been continued, and a few books of reference purchased. Three new cases have been procured for storage of books and periodicals. The total expenditure for these purposes is $340.

The Observatory buildings have been repainted at a cost of $195. No losses of property worthy of note have occurred during the year.

THE WORK OF THE OBSERVATORY.

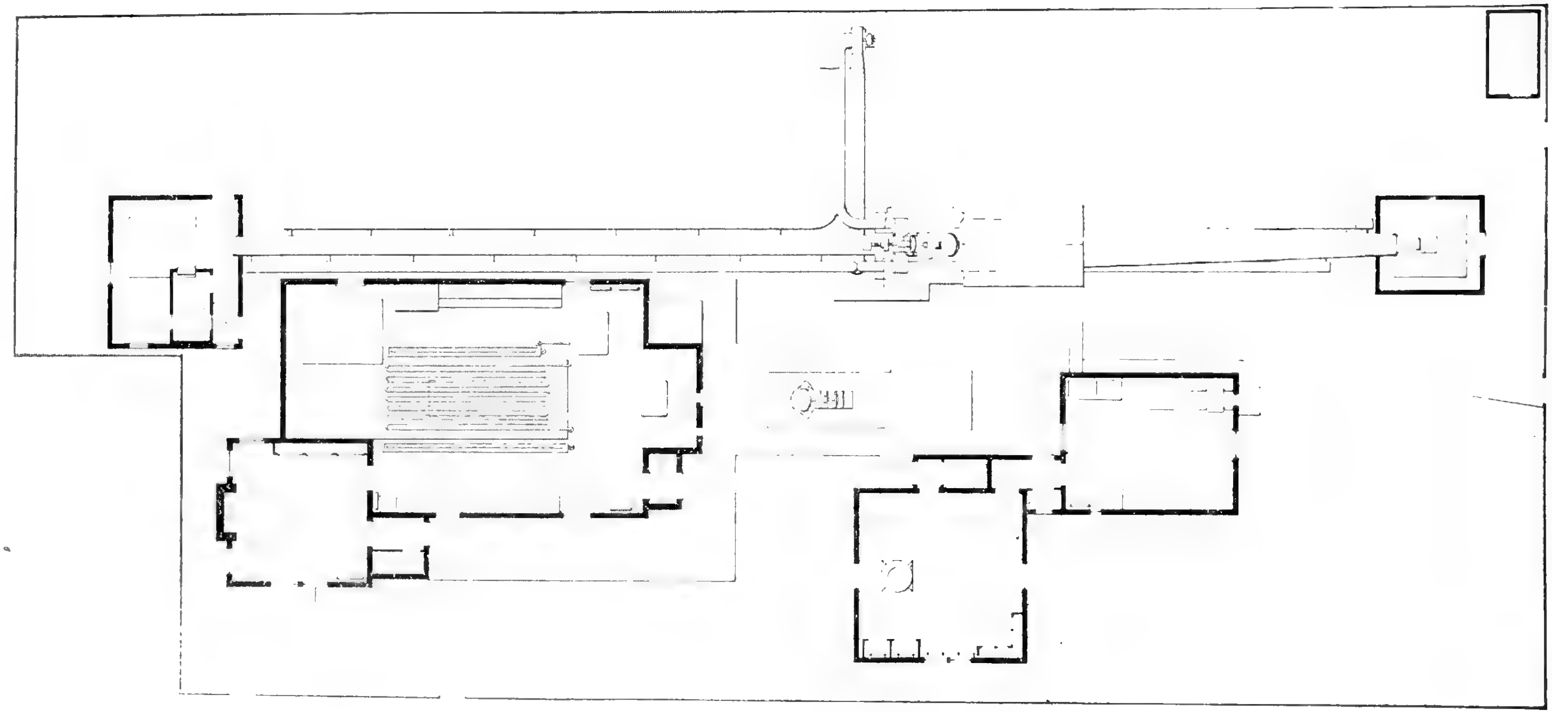
For convenience the work may be classified as follows:

1. Publications and miscellaneous matters.
2. Improvements of apparatus.
3. Investigations.

1. *Publications and miscellaneous matters.*

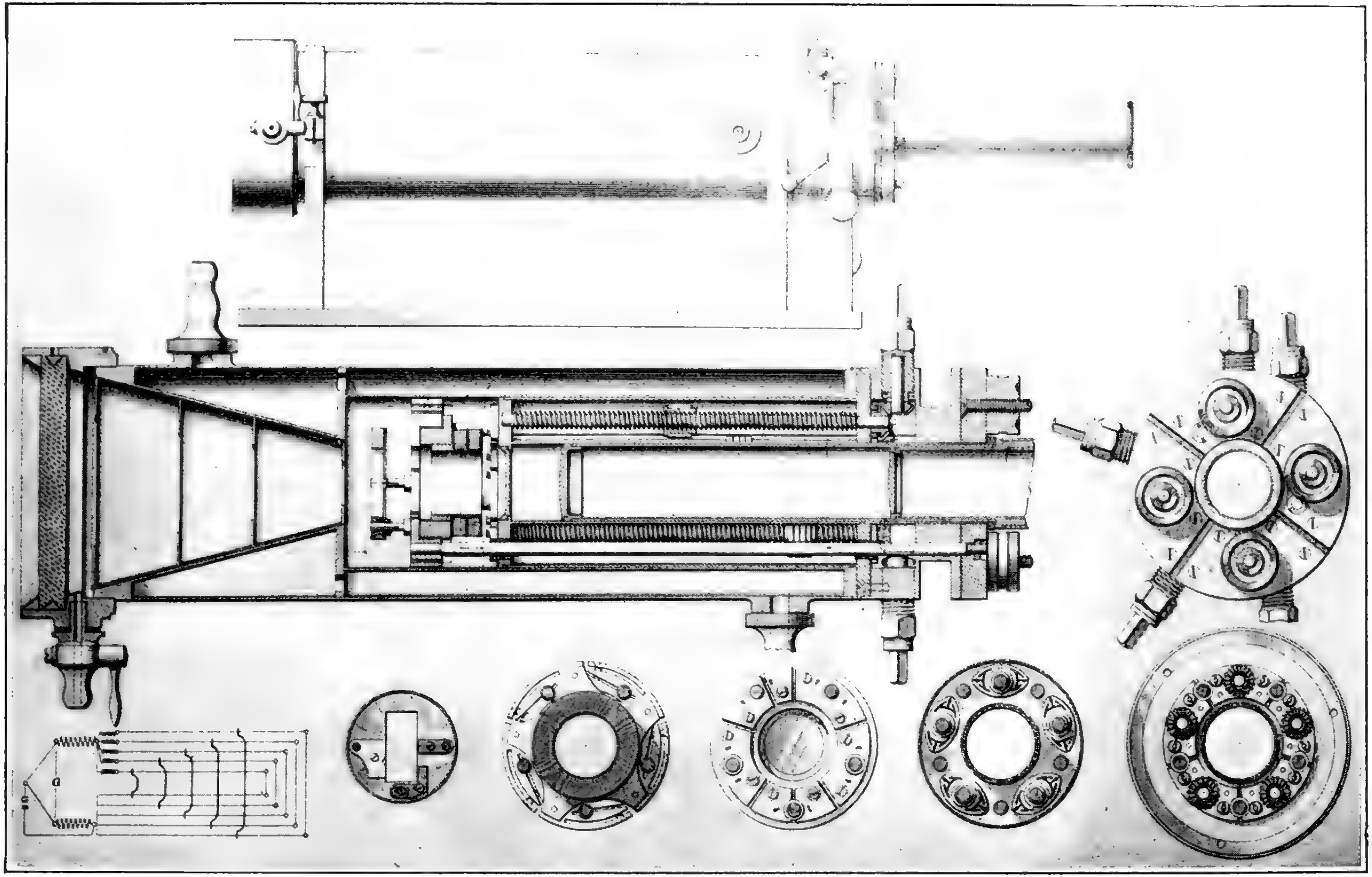
Eclipse report.—The report of the solar eclipse expedition to Wadesboro, N. C., of May, 1900, referred to in my last year's report, has been distributed, and has been favorably noticed both in this country and abroad.

St. Louis Exposition.—A far more elaborate exhibition of the Observatory work than usual has been prepared and installed for the St. Louis Exposition under your instructions. The great coelostat, mentioned in my last year's report, is arranged to throw a beam of sunlight into a darkened portion of the room occupied by the Observatory exhibit, where a solar image about a yard in diameter is thrown up by a 6-inch telescope, and the solar spectrum is formed upon the walls of the room by a large concave grating.



GROUND PLAN OF THE OBSERVATORY INCLOSURE.

Scale $\frac{1}{300}$ actual size.



NEW FORM OF BOLOMETRIC APPARATUS.

Side view, $\frac{1}{4}$ actual size; details, $\frac{3}{8}$ actual size.

A display of transparencies showing apparatus, buildings, and results of observation is a prominent object to visitors as they enter the room, and thence they pass through the darkened chamber above mentioned and get a view of the solar spectrum and of such sun spots as are visible. As they leave the darkened chamber they come upon a group of bolometric apparatus in actual operation and sensitive enough to give 100 or more scale divisions deflection when the visitor holds his hand in front of the bolometer. Charts and reports illustrative of the work of the Observatory are found upon the walls. A large number of copies of a pamphlet descriptive of the Observatory and its studies have been freely distributed.

2. *Improvements of apparatus.*

Bolometer.—The bolometer and its adjuncts had reached so high a state of perfection, as described in my last year's report, that further improvement could hardly be expected, but in order to make it practicable to set up so sensitive an instrument at the St. Louis Exposition and leave it without expert attention for months, it was felt desirable to combine in compact form the most approved methods of construction, having special reference to simplicity of manipulation, so that the instrument could be safely left in unskilled hands. Accordingly the bolometric apparatus, shown in Plate VI, was designed at the Observatory and constructed in the Observatory shop.

As in the form shown in Plate XII A of Volume I of the Annals of the Astrophysical Observatory, all the adjuncts to the bolometer, excepting the battery and galvanometer, are combined in a single case, adjusted mechanically from outside, but in this new form the adjusting slide wires are straight, instead of spiral, and no clamping mechanism is required, so that the construction is much simplified and can hardly get out of order. At the same time five slide wires are provided of differing sensitiveness of adjustment, so that by merely turning cranks on the outside of the case any adjustment from $\frac{1}{200}$ to $\frac{1}{200000000}$ in the relative resistances of the balancing arms of the bolometric circuit can be easily effected. It is a principal advantage of this arrangement that all the electrical circuit is in such compact quarters that changes of temperature affect all parts almost alike. These have been the great causes of disturbance of the deflections of the needle in the past, and the great obstacle to an automatic registry. Their bad effects are so nearly eliminated now that apart from the occasional need of a uniformity in the temperature of the prism, the elaborate arrangements for keeping a uniform temperature in the observing room are no longer needed. No difficulty from drift or any disorder has ever been experienced with this adjunct to the bolometric apparatus, and it is so much superior to any earlier form that a duplicate piece has since been constructed for use in a research on the radiation of the stars. Both were made at the Observatory shop and worked perfectly from the very first trial, and they reflect great credit on Mr. Kramer, the instrument maker.

Pyrheliometer.—Reference was made in last year's report to the new form of absolute pyrheliometer then being developed, consisting of a hollow chamber or "absolutely black body" in which the radiation is absorbed and from which the heat is continuously removed by a liquid circulating about the walls of the chamber. This instrument has been tried so successfully in an experimental form that steps are now being taken to provide one for continuous automatic registration of the rate of solar radiation. Its principal advantage as an absolute instrument depends on the fact that it may be demonstrated that its indications are correct, for if a known quantity of heat is supplied electrically to a coil within the chamber, this heat will reach the walls by convection and radiation, and being then removed by the flowing liquid its amount may be measured and compared with the known heating actually produced in the coil. But it is obvious that the heat of solar rays, absorbed almost wholly upon the wall of the chamber as they fall upon it, is much more likely to be accurately measured than the heat of the coil, which must first be chiefly communicated to the air

and thence to the wall of the chamber by convection. Accordingly, if the measured heating from the coil agrees closely with the known heating applied to the coil, much more closely will the measured heating from the solar rays represent the actual rate of solar radiation.

Repeated trials have showed that the new form of pyrheliometer is capable of accurate measurement of the heating of the coil, so that confidence is felt in its measures of the more advantageously applied solar radiation. Preliminary comparisons with the new instrument seem to indicate that the mercury pyrheliometer heretofore used as a standard at this Observatory reads somewhat too high.

Horizontal telescope.—Tests have been made to determine how completely the defects of bad seeing are removed by churning the air column in the great horizontal telescope, according to the plan initiated by you and mentioned in my last year's report. It has been found that though the churning is of great advantage, and generally indispensable to any work whatever on the solar image, yet the definition of an artificial star, whose beam travels twice through the whole tube, is far from perfect even with churning. Much of the disturbed seeing is found to be caused by the heating of the poorly protected tube in the sun, and a ventilated canvas tent has been ordered to screen the tube thoroughly. Plans are also formed for making additional tests on other methods of churning the air in the tube. Recalling the more perfect results secured in experiments on a smaller scale in 1902, and the evident improvement of definition obtained in the present large tube with the churning device now installed, no doubt is felt that bad seeing within the tube itself may at length be wholly removed.

A second serious defect in definition was found to be caused by warping of the large plane mirrors of the coelostat, one of which is inclined forward and was at first supported by a ring in front, while the other mirror, made originally for much less severe work, was too thin to keep flat with an ordinary system of support. Both mirrors have been almost entirely cured of these defects by the introduction of the Ritchey supporting system composed of numerous balanced plates.[a] For the mirror which is inclined forward, Mr. Ritchey's original design had to be somewhat modified because the mirror must be stuck to the plates instead of resting on them by its weight as in mirrors supported face up. We have heretofore employed here ground brass plates to which the mirror is stuck with rubber cement, but it would probably be better to make the plates slightly concave and connect them by flexible tubes to a large reservoir from which the air is partially exhausted, so that the mirror would be held to the plates by suction. But even as we have used it, the Ritchey system has wonderfully improved the definition secured on the solar image. All the work on these support systems was done in the Observatory shop.

A third serious defect in the definition of the horizontal telescope is due to the tremor of the mirrors continually kept up by the city traffic, notwithstanding the costly and massive piers on which the apparatus rests. Very great improvement in steadiness has come from placing 1½-inch rubber blocks under the coelostat and under the concave mirrors.

Before the improvements noted, the solar focal image, 40 cm. in diameter, was an ill-defined circle at a focal distance varying often 10 feet during a single day, and with the sides at different focal distances from the top and bottom. Now the image is pretty sharply defined, comes to focus on all sides in the same plane, and stays within less than a foot of the same focus all day; while its wanderings rarely reach much over a millimeter in amplitude. It is now possible to observe the absorption in the solar envelope with accuracy at within 1 or 2 per cent of the radius from the sun's limb. But further improvements of the horizontal telescope are in progress, notably the provision of well-protected shelters over the coelostat, the concave mirror, and

[a] Astrophysical Journal, v, 143, 1897.

the spectro-bolometric apparatus, in place of the canvas shelters thus far used, and with these, the improved churning device proposed, and the tent to shelter the tube already ordered, it is confidently expected to have the horizontal telescope in very satisfactory condition during the coming fiscal year.

3. *Investigations.*

Sun's possible variability.—Notable progress has been made with the researches you have initiated on the amount of solar radiation and its absorption in the solar envelope and in our atmosphere. Within the last seventeen months three independent kinds of evidence have been collected here, pointing toward the conclusion that the radiation supplied by the sun may perhaps fluctuate within intervals of a few months through ranges of nearly or quite 10 per cent, and that these fluctuations of solar radiation may cause changes of temperature of several degrees centigrade nearly simultaneously over the great continental areas of the world. Further evidence must, however, be awaited to verify this important conclusion.

The three kinds of evidence referred to are as follows: First, on all favorable days the "solar constant" of radiation outside our atmosphere has been determined here, and changes of about 10 per cent in the values obtained have been found which can not be attributed to known causes. Second, the solar image formed by the horizontal telescope has been examined with the spectro-bolometer to determine the absorption of radiation within the solar envelope itself. If we grant for argument's sake that the rate of solar radiation outside our atmosphere fluctuates rapidly from time to time, then as you have observed, the cause of this fluctuation can not reasonably be a variability of the temperature of so immense a body as the sun itself, but must rather be in a change in the absorption of a more or less opaque envelope surrounding the sun. Accordingly the two researches I have mentioned are intimately associated, for if we find a considerable increase in the rate of solar radiation outside our atmosphere we ought to find a corresponding decrease in the absorbing power of the solar envelope.

Such is in fact one of the most notable results of the year's work. In August, September, and October, 1903, the observations of the "solar constant" of radiation indicated that the rate of radiation was about 10 per cent below that observed in February, 1904. On the other hand measurements of the absorption of the solar envelope indicated considerably less absorption in February, 1904, than in September, 1903.

The third kind of evidence of change in solar radiation is based on a study of the temperature of the North Temperate Zone, as indicated by the Internationaler Dekadenberichte published by the Kaiserliche Marine Deutsche Seewarte, and received at the Observatory through the kindness of the Librarian of the United States Weather Bureau. This publication gives the mean temperature at 8 a. m. for each ten days at each one of about one hundred stations distributed over the principal land areas of the North Temperate Zone, and for about ninety of these stations there is also given the normal temperatures for the same ten-day periods, representing the mean of many years. From these data there have been computed here the temperature departures from the normal since January 1, 1903, and these are compared graphically in the accompanying chart, Plate VII,[a] with the measures of the solar constant made in 1903. It will be seen that shortly after the observed fall of solar radiation in March, 1903, a general fall of temperature occurred, which would be a natural result of such a change. It has been shown here, in accordance with the known laws of radiation, that 10 per cent fall in the solar radiation could not produce more than 7°.5 C. fall in terrestrial temperatures, and that several causes, notably

[a]Shown also in your article on "A Possible Variation of the Solar Radiation," Astrophysical Journal, June, 1904.

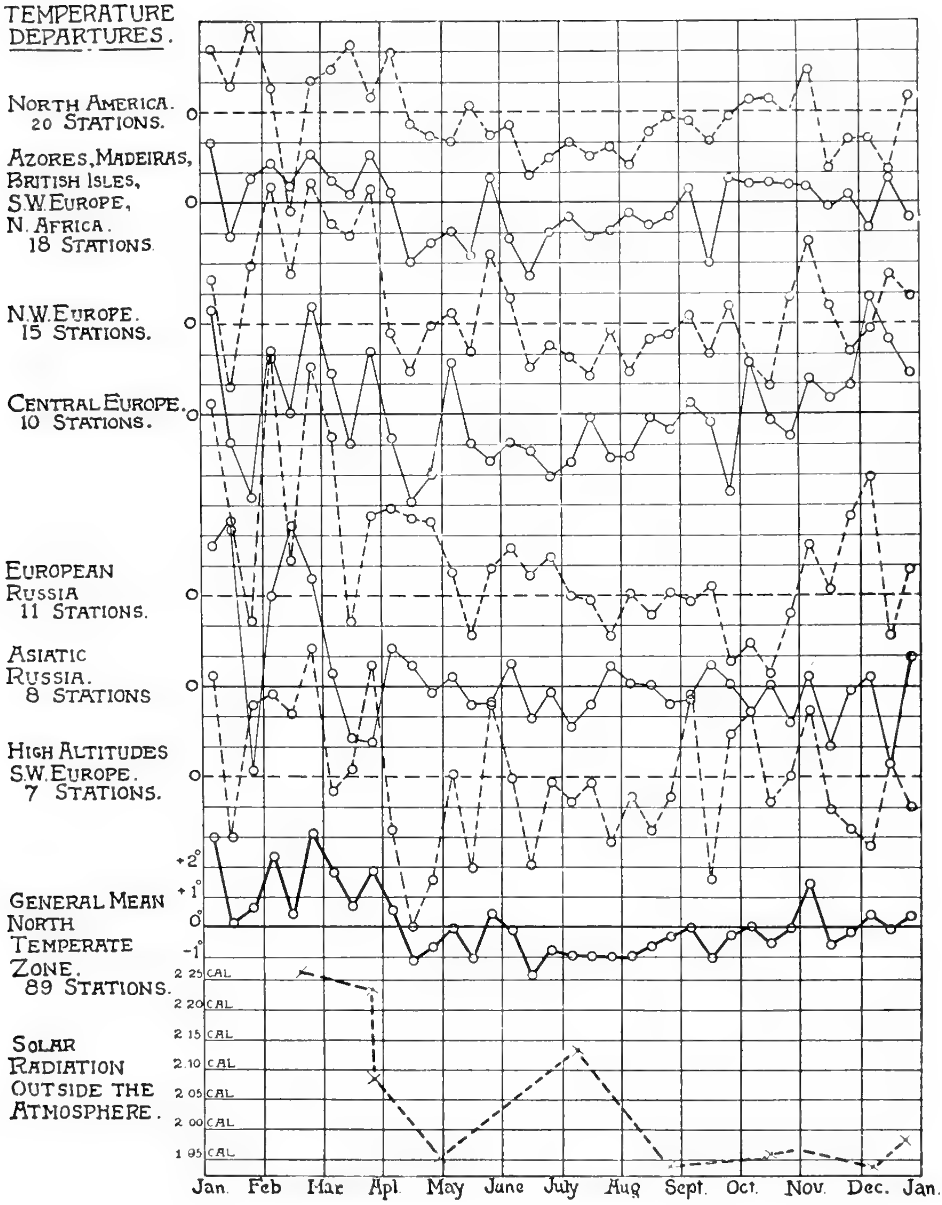
the presence of the oceans, would prevent so great a change of temperature as this resulting from a temporary diminution of solar radiation of only a few months' duration. The observed fall of about 2°.5 C. in the mean temperature of the land areas of the North Temperature Zone during April, 1903, seems to be therefore in good accord with the observations of solar radiation.

Owing to the uncommon cloudiness of the first six months of 1904 few measures of the "solar constant" worthy to be compared with the series of 1903 have been obtained, but taking the best of the measures it appears that high values of solar radiation in February, 1904, and lower ones in the subsequent months are indicated, as shown in Table 2, given below. This appears to be in general accord with the mean temperatures observed over the North Temperate Zone, except that it seems probable that the solar radiation was high in January as well as February, but the lack of good observing weather prevented our recognition of it.

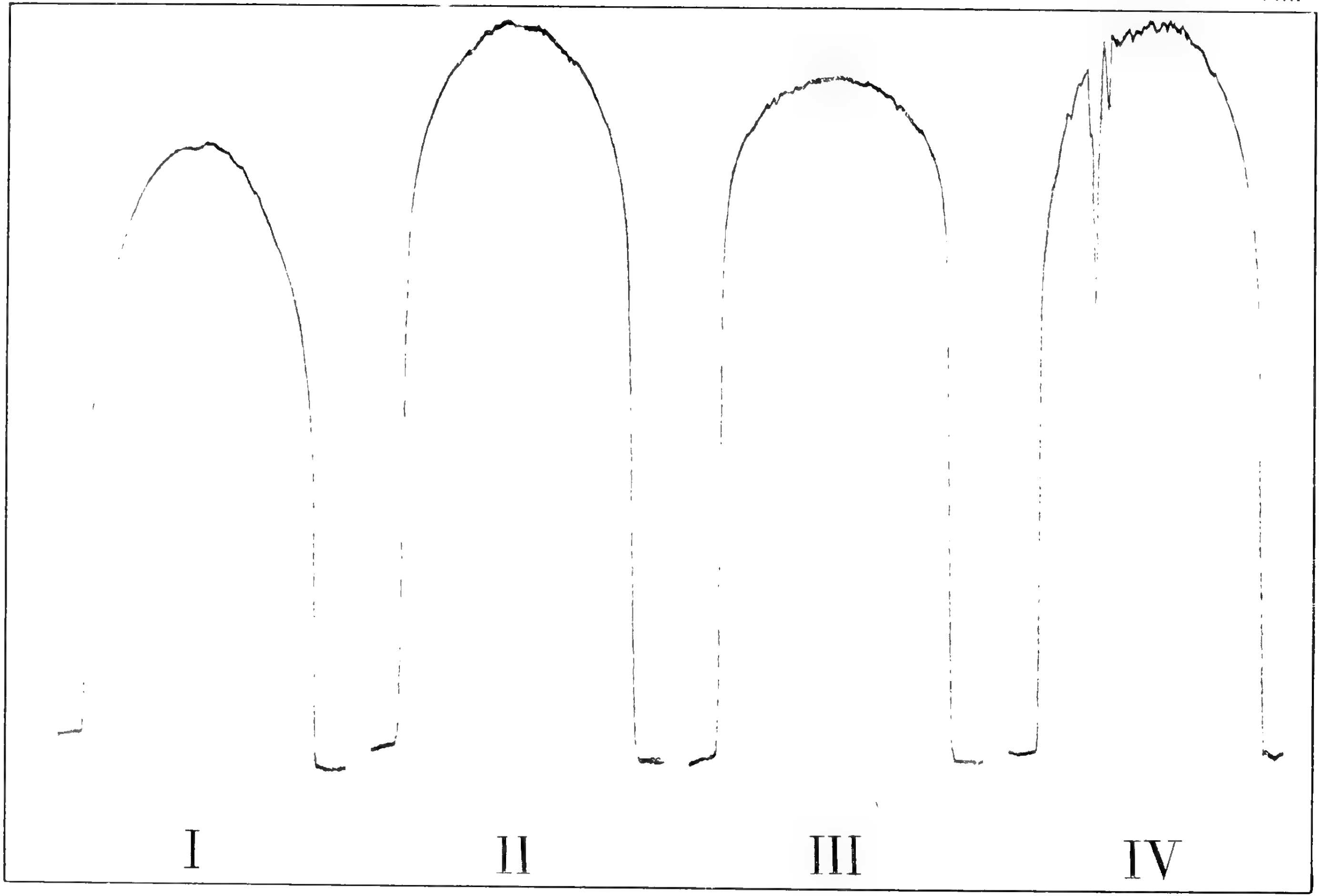
Forecasts of temperature.—If subsequent research shall confirm these indications of a general parallelism between measures of solar radiation and terrestrial temperatures, we are now entering upon a new field of climate forecasting. But if such forecasts had to depend on measures of the solar radiation outside our atmosphere the observing station should be removed from Washington to a more favorable situation, for the experience of the last two years has shown that hardly a score of days in a year are uniformly clear enough to allow even relatively good "solar constant" values to be obtained, and these good days are very unevenly distributed. Fortunately, the distinct work which you have planned on the absorption of the solar envelope, already mentioned, seems to promise a far easier method of forecasting, which requires much less of constancy in the atmospheric conditions. Owing to the preliminary nature of the installation of the great horizontal telescope as thus far used, and to the fact that the great coelostat has been sent to the exposition at St. Louis, only the single instance above mentioned of a comparison of the radiation outside our atmosphere with solar absorption has yet been made; but if future work shall confirm the general agreement between the indications afforded by the study of the absorption of the solar envelope and those afforded by the measures of total solar radiation, the significance of the result will be very great, for the bolometric investigation of the solar image can be made at any time when the sun shines clear for five minutes, by a method practically independent of the disturbances of our own atmosphere, whereas the measures of total radiation require three hours of unvarying transparency of the air. Accordingly the former measurements may be made almost daily, and will, it is hoped, prove of great service in temperature forecasts.

The effects of changes of the transparency of our own atmosphere are, perhaps, of equal importance in temperature forecasts, and the recognition of these of course depends on such spectro-bolometric measures as are involved in determinations of the "solar constant." Referring to my last year's report, it will be remembered that the earlier months of 1903 were found distinguished by more than the average absorption of light in our atmosphere. In September, 1903, there was a marked increase in transparency, so that in the latter months of the year the clearness was almost as great as that of 1901–2. Of course as these studies are made only at Washington no general conclusions as to the transparency of the air at other stations can safely be drawn. But if the clearing above mentioned was general it might perhaps explain the upward tendency during the last months of 1903 of the curve of average temperatures shown in Plate VII.

I venture to think the importance of studies of atmospheric absorption at other stations would warrant observers elsewhere in taking up the spectro-bolometric work involved in measures of the "solar constant." Measures of the absorption of the solar envelope, on the other hand, which require the provision of a great solar image, would not necessarily be duplicated elsewhere.



TERRESTRIAL TEMPERATURE AND SOLAR RADIATION, 1903.



INTENSITY OF RADIATION ALONG DIAMETER OF SOLAR DISC, SEPTEMBER, 1903.

I, At wave length 0.55μ; II, at wave length 1.00μ; III, at wave length 1.60μ; IV, all wave lengths, but including sun spot.

RESULTS IN DETAIL.

Referring to my report of last year and to your recent publication[a] on "A possible variation of solar radiation" for further information, the following three tables summarize the detailed results of the work already broadly discussed. Tables 1 and 2 are given in continuation of similar tables in last year's report, and perhaps it needs only to remark concerning them that the first six months of 1904 have proved uncommonly unfavorable to such studies as are here set forth, by reason of unusual cloudiness. Owing to the bad atmospheric conditions there have been no days when results as satisfactory as many of those of 1903 have been secured, and only two days' work of 1904, February 11 and May 28, are regarded here as worthy of much confidence. Taking the whole series together and comparing with the results of 1902–3, it appears probable, however, that excepting during the month of February, the solar radiation thus far in 1904 has been below the normal, although not so low as during the latter half of 1903. The atmospheric transmission of 1903–4 seems to be generally below that of 1902.

TABLE 1.—*Coefficients of atmospheric transmission for radiation from zenith sun.*

Wave length	μ 0.40	μ 0.45	μ 0.50	μ 0.60	μ 0.70	μ 0.80	μ 0.90	μ 1.00	μ 1.20	μ 1.60
Date.	Transmission coefficients for unit air mass.									
1903.										
July 7	0.42	0.60	0.66	0.69	0.77	0.82	0.85	0.86	0.88	0.89
August 24	.40	.51	.59	.69	.78	.84	.86	.87	.89	.90
September 14	.52	.71	.80	.82	.87	.90	.91	.92	.93	.93
October 14	.64	.70	.76	.80	.85	.88	.89	.91	.91	.92
October 29	.53	.59	.64	.75	.80	.82	.83	.85	.88	.91
December 7	.59	.65	.75	.82	.85	.87	.89	.92	.94	.95
December 23	.64	.70	.75	.79	.85	.89	.90	.91	.92	.94
1904.										
January 27	.60	.67	.73	.73	.79	.86	.90	.91	.91	......
February 11	.42	.56	.59	.59	.69	.78	.84	.89	.92	.95
April 4	.42	.63	.67	.72	.79	.85	.88	.89	.91	.94
April 21	......	.45	.60	.67	.76	.82	.85	.88	.89	.92
May 12	.35	.55	.71	.79	.83	.86	.89	.90	.92	.95
May 28	.40	.57	.63	.77	.83	.87	.90	.90	.90	.91
General mean	.494	.607	.683	.741	.802	.848	.876	.893	.908	.926
Mean, July 1, 1903, to January 1, 1904	.534	.637	.707	.766	.821	.860	.876	.887	.907	.920
Mean, January 1, 1904, to July 1, 1904	.436	.572	.655	.710	.777	.835	.876	.898	.909	.930

[a] Astrophysical Journal, June, 1904. Phil. Mag., July, 1904.

TABLE 2.—*Values of the solar constant of radiation outside the earth's atmosphere.*

Date.	Character of the observation.	Hour angle west.	Air mass.	Solar radiation per square centimeter per minute— At earth's surface.	Outside atmosphere corrected to mean solar distance.
1903.		*h. m.*		*Cal.*	*Cal.*
July 7	Fair	0 51	1.07	1.31	2.16
Do	do	3 36	1.51	1.10	2.11
August 24	Good	1 17	1.18	1.14	1.93
Do	do	1 47	1.24	1.12	1.95
October 14	do	1 58	1.72	1.23	1.98
Do	do	2 25	1.88	1.18	1.94
October 29	do	0 59	1.69	1.13	1.97
December 7	do	2 45	3.34	.92	1.94
December 23	do	1 39	2.52	1.16	1.96
Do	do	2 41	3.38	1.02	2.01
1904.					
January 27	Fair	1 49	2.20	1.18	2.05
Do	do	2 55	2.98	.99	1.98
February 11	do	1 19	1.81	1.18	2.29
Do	do	2 29	2.27	1.02	2.24
April 4	Indifferent	0 37	1.21	1.39	2.08
Do	do	3 12	1.72	1.25	2.15
May 12	do	0 31	1.08	1.29	1.90
Do	do	3 35	1.59	1.19	2.07
May 25	do	3 35	1.53	1.08	2.24
Do	do	4 25	1.94	.96	2.31
May 28	Fair	1 14	1.09	1.42	2.14
Do	do	4 15	1.81	1.16	2.05

Mean value of direct atmospheric transmission.—Since Table 2 was prepared, which was done without any reference to the subject of the present paragraph, at your request the numbers in the fifth column have been corrected to represent the solar radiation at the earth's surface for zenith sun, and those in the sixth column to actual rather than mean solar distance. The ratio of the amount of heat which reaches the earth's surface for zenith sun to that outside the atmosphere is then obtained by dividing the former values by the latter, and the mean result is 68 per cent; whence the average absorption in our atmosphere is found to be 32 per cent, which is the amount by which the sun's radiation is diminished in a vertical transmission to the surface of the earth. In this connection attention may be invited to a paper published by you in the American Journal of Science, as long since as September, 1884, in which you have stated that observations made up to that time by the best authorities gave a value of absorption for the zenith sun of about 20 per cent, and that owing chiefly to the neglect of selective absorption, this nearly unanimous value is nevertheless far inferior to the truth. The value just deduced from selective absorption methods may be consided as a confirmation of your then statement.

You have elsewhere stated that the solar constant values obtained from high and low sun measures at a low altitude station are likely to be below rather than above the truth, and it may at least be admitted that there is a certain direct reflection of radiation in passing from outer space into our atmosphere, differing as it does from space in its optical density, and that a portion of radiation is here lost which can not

be measured at any single station high or low. Accordingly we must suppose that our solar constant values are diminished from one or both the above causes, and hence that the atmospheric absorption here estimated is too little rather than too much.

TRANSMISSION OF SOLAR ENVELOPE.

TABLE 3.—*Preliminary values of coefficients of transmission in the solar envelope.*

Wave length	μ 0.45	μ 0.50	μ 0.60	μ 0.70	μ 0.80	μ 0.90	μ 1.00	μ 1.20	μ 1.60	μ 2.00
Date.	Coefficients for vertical transmission.									
1903. September 25	0.53(?)	0.58	0.66	0.70	0.72	0.75	0.77	0.80	0.83	0.84
1904. February 20	.62(?)	.65	.72	.76	.78	.80	.82	.85	.87	.88

Turning now to Table 3, which purports to give the vertical transmission for different wave lengths in the solar envelope, this depends but little on our own atmosphere, and much is hoped from a continuation of the work with the great horizontal telescope on which these results rest. As this work is but newly developed here, a short description of the procedure and assumptions involved in estimating the transmission of the solar envelope will not be out of place. A spectro-bolometer, provided with a slit only about 5 millimeters high, is set so that rays of a certain known wave length reach the bolometer from the slit. Then with the prism stationary, but with the automatic recording plate moving before the galvanometer as usual, the solar image is allowed to drift by the earth's diurnal motion across the slit of the spectro-bolometer. Thus is produced a curve like those shown in Plate VIII, in which horizontal distances from the center of the figure are proportional to distances along the radius of the solar disc, and the height of the curve is proportional to the intensity of the radiation of the given wave length at the corresponding point on the solar disc. Apparently the figure would be "flat-topped," if there was no absorption of the rays by the solar envelope, and the curvature of the figure gives a rough indication of the amount of the absorption.[a] If the curve for a given day's observation has steeper sides than that of another, greater absorption would be indicated for the former day, and such was the case for the two days' work represented in Table 3.

But in order to estimate quantitatively the change in absorption in the solar envelope, it is necessary to make two assumptions whose truth can as yet only be verified by the accuracy with which they represent the experimental results. First, it may be supposed that the radiation of the absorbing envelope is negligible compared with that of the photosphere, and that the absorption is, like that of the earth's atmosphere, represented by such an exponential formula as would apply to a homogeneous atmosphere. Second, the thickness of the absorbing layer being unknown, its relative thickness compared with the solar radius must be assumed in order to compute the exponent of the formula.

In the first computations made here it was assumed that the thickness of the absorbing envelope was very small as compared with the sun's radius. Upon this

[a] You have suggested the possibility that owing to a columnar structure of the solar surface we might find the limb of the sun brighter than the center of the disc in the absence of an absorbing envelope, by reason of our seeing near the limb only the supposedly brighter tops of the columns. No allowance for this is made in these preliminary computations.

basis logarithmic plots[a] prepared from the observed results showed great departures from straight lines for all wave lengths, so that either the absorbing layer is not so thin as first assumed, or the phenomenon is not a simple one of absorption. Acting on the former supposition, it was found that when the absorption was assumed to take place in a homogeneous stratum of about 45,000 miles thickness outside the photosphere, or in other words, a rather thick stratum, yet well within the thickness of the brighter part of the solar corona, very little curvature was exhibited in the logarithmic plots at any wave lengths, or for any distance less than 99 per cent of a radius from the center of the disc, or on either day of observation. Evidently the assumption of homogeneity is a very strained one, hardly perhaps to be tolerated even in a preliminary computation. I have, however, given the transmission coefficients found in this way in Table 3. Estimates have been prepared of the amount by which the total radiation of the sun would be increased were this envelope wholly removed, but these are so far dependent upon the assumption referred to that I defer their presentation for the present.

I wish, in closing, to particularly commend the zeal and ability with which Mr. F. E. Fowle, jr., has aided in carrying through all the work above reported. Mr. Fowle has also published[b] during the year a valuable study of the absorption of water vapor in the earth's atmosphere, which summarizes measurements and computations he has made from bolographic data collected here in the last three years. He finds the transmission in each of the water-vapor bands studied to follow Bouguer's exponential law, but with coefficients of transmission varying greatly in amount for different bands and for different wave lengths in the same band. In passing from band to band the absorption is generally greater the greater the wave length of the band, but taking each band by itself the shorter wave lengths are most absorbed.

CONCLUSION.

The work of the year has been distinguished by useful improvements in the apparatus of the Observatory, notably in the bolometer, the pyrheliometer, and the great horizontal telescope. But chiefly it is marked by a great advance toward what you have set as the far-off final goal of our efforts, namely, the establishment of a sound basis for long range forecasting of climate, in the study of the solar radiation, and its absorption in our atmosphere. The work of the year has made it seem possible, though not yet certain, that fluctuations of the amount of solar radiation as great as 10 per cent may occur, and that independently of them there are marked changes of the transparency of our atmosphere. Both causes must profoundly influence climatic conditions, and both are being studied here with increasing facility, accuracy, and success, by the aid of the spectro-bolometer. In short, it now seems not improbable that successful general forecasting of climate will be the not too far distant outcome of our work.

Respectfully submitted.

C. G. Abbot, *Aid in Charge.*

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

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[a] Compare Plate VI of last year's report.

[b] Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. II, Part 1.

Appendix VI.

REPORT OF THE LIBRARIAN.

Sir: I have the honor to present the following report on the operations of the library of the Smithsonian Institution for the fiscal year ending June 30, 1904.

The number of publications received and recorded in the accession books of the Smithsonian deposit, Library of Congress, is as follows:

	Quarto or larger.	Octavo or smaller.	Total.
Volumes	526	1,760	2,286
Parts of volumes	10,296	6,022	16,318
Pamphlets	623	4,526	5,149
Charts			215
Total			23,968

The accession numbers run from 452466–460376.

A few of these publications have been temporarily held at the Institution for the use of the staff, but the larger number have been sent direct to the Library of Congress.

About 355 boxes and 18 packages were used in transmitting the sendings to the Library of Congress, and they are estimated to have amounted to the equivalent of 14,920 octavo volumes. This does not include a large number of public documents presented to the Institution and transmitted without being recorded.

The selecting and sending to the Library of Congress of volumes and parts of volumes belonging to the Smithsonian deposit which had been held at the Institution and Museum in the past has been carried on in connection with the other work of the library, and while a large number have been sent up there still remain from last year many volumes ready for checking on the accession books. No separate count has been kept of these sendings, and they are included in the above estimate.

The libraries of the Secretary, Office, and Astrophysical Observatory have received during the year 337 volumes, pamphlets and charts, and 2,048 parts of volumes, making a total of 2,385, and a grand total, including books for the Smithsonian deposit, of 26,353.

The parts of serial publications that were entered on the card catalogue numbered 24,126. Six thousand slips for completed volumes were made, and about 510 cards for new periodicals and annuals were added to the permanent record from the periodical-recording desk.

Inaugural dissertations and academic publications were received from universities at the following places:

Baltimore (Johns Hopkins).
Basel.
Berlin.
Bern.
Bonn.
Breslau.
Erlangen.
Freiburg.
Giessen.
Geneva.
Greifswald.
Halle.
Heidelberg.
Helsingfors.
Ithaca (Cornell).
Jena.
Kiel.
Konigsberg.
Lafayette (Purdue).
Leipsic.
Louvain.
Marburg.
New York (Columbia).
Paris.
Philadelphia (University of Pennsylvania).
Rostock.
St. Petersburg.
Toulouse.
Tubingen.
Utrecht.
Wurzburg.
Zürich.

The plan inaugurated by the Secretary to effect new exchanges and to secure missing parts to complete sets, has been continued. In doing this 945 letters were written and 285 new periodicals were added to the receipts, together with the completion of 349 defective series. The sending out of postal cards for missing numbers has been continued, and 105 were mailed, with the result that 53 missing parts were received in response.

In the reference room the members of the scientific staff and others have consulted the transactions and proceedings of the learned societies; and in the reading room 20 bound volumes of periodicals and 2,900 separate periodicals were taken out for consultation. The sections maintained in the Institution are the Secretary's library, Office library, and the Employee's library, together with the sectional libraries of the Astrophysical Observatory, Aerodromics, International Exchanges, and Law Reference.

At the close of last year 64 volumes in the Astrophysical Observatory library had just been completed and made ready for binding, and in the early part of this year they were bound.

The collection of books in the library at the National Zoolgical Park has had an addition, by purchase, of 15 works on the life and habits of animals and birds, and one or two exchanges of periodical publications have been effected by the Institution for its special benefit.

The employees have availed themselves of the privileges of the Employee's library, and 3,220 books were borrowed, that number being a considerable increase over last year. The library has had an addition, by purchase, of 37 new books, and 120 magazines were bound. The sending of a collection of books, numbering about 40, each month to the National Zoological Park has been continued with such success that an arrangement was made in the early part of June to make a similar sending to the Bureau of American Ethnology, and a case containing about 26 volumes was sent.

The increase in the number of books presented by General de Peyster, for the Watts de Peyster collection Napoléon Buonaparte, created the necessity for more shelf room, and 22 cases were constructed to hold the additions to this collection that have been received during the last two years. These cases were placed against the north and south walls of the lower corridor of the office wing of the Institution. General de Peyster continues to add many valuable volumes to the collection, together with several bronze busts. There have also been received from him oil paintings and many historical relics of the colonial period, which have been placed in the United States National Museum for exhibition.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The work of the International Catalogue has been continued under the auspices of the Institution, and the addition to the allotment for this year has made possible the increase of nearly 50 per cent in the total number of references sent to the central bureau at London. The following table gives the number in detail:

Literature of 1901	3,044
Literature of 1902	9,424
Literature of 1903	8,745
Total	21,213

All of the first annual issue of the catalogue has now been published and distributed, together with the following volumes of the second annual issue: Astronomy, Bacteriology, Mechanics, Physics, Mathematics, Mineralogy, and Physical Geography. This country still leads in the number of subscribers to the catalogue.

In the near future an effort will be made looking to a more complete cooperation of the authors and publishing bodies in the United States with this Regional Bureau by requesting immediate notice and subject abstract of new publications coming within the scope of the International Catalogue.

The international convention, which has the power of revision of the classification schedules, will meet in London in July, 1905, and has asked for suggestions from this country through the Smithsonian Institution.

MUSEUM LIBRARY.

The National Museum library has received a gift from Prof. Otis Tufton Mason, in addition to the one of some years ago, of about 2,000 pamphlets, separates, and bound quarto volumes, mostly on anthropological subjects. A special book plate has been provided for this collection. The Museum has also received from Dr. Edward L. Greene his entire botanical library, which has been placed on deposit for a period of ten years in connection with his botanical collection. The conditions regarding Doctor Greene's library are that the books shall be accessible on the same terms as other books in the Museum library, with the exception that they are not to be lent to persons outside the District of Columbia or abroad without Doctor Greene's consent. In case of the death of Doctor Greene during the time specified, the library becomes the property of the United States.

In the Museum library there are now 20,548 bound volumes and 35,950 unbound papers. The additions during the year consisted of 1,504 books, 3,187 pamphlets, and 700 parts of volumes. There were catalogued 938 books, of which 40 belonged to the Smithsonian deposit, and 2,130 pamphlets, of which 70 belonged to the Smithsonian deposit, and 11,520 parts of periodicals, of which 1,887 belonged to the Smithsonian deposit. In the accession book 1,387 volumes, 2,187 pamphlets, and 629 parts of volumes were recorded. The number of cards added to the authors' catalogue were 4,090, which does not include 2,855 cards for books and pamphlets recatalogued.

In connection with the entering of periodicals 171 memoranda were made reporting volumes and parts missing in the sets, together with a few titles of publications which were not represented in the library. The result of this work was the completing, or partly filling up, of 70 sets of periodicals.

The number of books, pamphlets, and periodicals borrowed from the general library amounted to 26,456, including 5,679, which were assigned to the sectional libraries.

There has been no change in the sectional libraries established in the Museum, and they are as follows:

Administration.
Administrative assistant.
Anthropology.
Biology.
Birds.
Botany.
Children's room.
Comparative anatomy.
Editor.
Ethnology.
Fishes.
Geology.
History.
Insects.
Mammals.
Marine invertebrates.
Materia medica.
Mesozoic fossils.
Mineralogy.
Mollusks.
Oriental archæology.
Paleobotany.
Parisites.
Photography.
Prehistoric archæology.
Reptiles.
Stratigraphic paleontology.
Superintendent.
Taxidermy.
Technology.

In the following table are summarized all the accession for the Smithsonian deposit for the libraries of the Secretary, Office, Astrophysical Observatory, United States

National Museum, and National Zoological Park. That of the Bureau of Ethnology is not included, as it is separately administered:

Smithsonian deposit	23,968
Secretary, Office, and Astrophysical Observatory libraries	2,385
United States National Museum library	5,491
National Zoological Park	17
Total	31,861

Respectfully submitted.

CYRUS ADLER, *Librarian.*

MR. S. P. LANGLEY,

Secretary of the Smithsonian Institution.

JULY 29, 1904.

Appendix VII.

REPORT OF THE EDITOR.

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its bureaus during the year ending June 30, 1903:

I. CONTRIBUTIONS TO KNOWLEDGE.

To the series of Contributions four memoirs have been added during the last year.

1413. Hodgkins fund. On the Absorption and Emission of Air and its Ingredients of Wave Lengths from 250 $\mu\mu$ to 100 $\mu\mu$. By Victor Schumann. City of Washington: Published by the Smithsonian Institution, 1903. Quarto. Pages iv, 30, 4 plates. Part of Vol. XXIX.

1414. The Whalebone Whales of the Western North Atlantic Compared with those Occurring in European Waters with Some Observations on the Species of the North Pacific. By Frederick W. True. City of Washington: Published by the Smithsonian Institution, 1904. Quarto. Pages vii, 332, 50 plates, 97 text figures. Vol. XXXIII, Contributions to Knowledge. [In press.]

1438. A Comparison of Features of the Earth and the Moon. By N. S. Shaler. City of Washington: Published by the Smithsonian Institution, 1903. Quarto. Pages v, 79 (explanation of plates, pp. 81–130), 25 plates. Part of Vol. XXXIV.

1459. On the Construction of a Silvered Glass Telescope of Fifteen and a half Inches in Aperture, and its Use in Celestial Photography, by Henry Draper; and The Modern Reflecting Telescope and the Making and Testing of Optical Mirrors, by George W. Ritchey. City of Washington: Published by the Smithsonian Institution, 1904. Quarto. Pages 55 + 51, 13 plates. [In press.] Part of Vol. XXXIV.

II. SMITHSONIAN MISCELLANEOUS COLLECTIONS.

To the Miscellaneous Collections 36 numbers have been added, most of them being articles published in the Quarterly Issue recently established to meet a special need for early publication of scientific papers.

1374. Index to the Literature of Thorium, 1817–1902. By Cavalier H. Joüet. City of Washington: Published by the Smithsonian Institution. Octavo. Pages 154.

1417. Phylogeny of Fusus and its Allies. By Amadeus W. Grabau. Octavo. Pages iii, 157 (158–192 explanation of plates), 18 plates, 21 text figures.

1419. Smithsonian Miscellaneous Collections, Vol. XLV. (Quarterly Issue, Vol. I, parts 1–2. July–September, 1903.) City of Washington: Published by the Smithsonian Institution, 1904. Octavo. Pages 223, 56 plates, 28 text figures.

1420. Seventy New Malayan Mammals. By Gerrit S. Miller, jr. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 1–73, plates i–xix, 1 text figure.

1421. Recent Studies of the Solar Constant of Radiation. By C. G. Abbot. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 74–83, plates xx–xxii.

1422. The new Cœlostat and Horizontal Telescope of the Astrophysical Observatory of the Smithsonian Institution. By C. G. Abbot. Reprinted from the Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 84–90, plate xxiii.

1423. On Some Photographs of Living Finback Whales from Newfoundland. By Frederick W. True. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 91–94, plates XXIV–XXVI, 1 text figure.

1424. A Skeleton of Hesperornis. By Frederic A. Lucas. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Page 95, plate XXVII.

1425. A New Plesiosaur. By Frederic A. Lucas. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Page 96, plate XXVIII.

1426. Shell Ornaments from Kentucky and Mexico. By W. H. Holmes. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 97–99, plates XXIX–XXX.

1427. On the Glacial Pothole in the National Museum. By George P. Merrill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 100–103, plate XXXI.

1428. Notes on the Herons of the District of Columbia. By Paul Bartsch. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 104–111, plates XXXIII–XXXVIII.

1429. Preliminary Report on an Archæological Trip to the West Indies. By J. Walter Fewkes. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 112–133, plates XXXIX–XLVIII.

1430. Form Regulation in Cœlentera and Turbellaria. By C. M. Child. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 134–143.

1431. New Genera of South American Fresh-water Fishes, and New Names for some old genera. By Carl H. Eigenmann. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 144–148.

1432. Korean Headdresses in the National Museum. By Foster H. Jenings. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV Pages 149–167, text figures 3–28.

1433. The Hodgkins Fund of the Smithsonian Institution. By Helen Waldo Burnside. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 168–174, plate L.

1434. A Notable Success in the Breeding of Black Bears. By Arthur B. Baker. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 175–179, plates LI–LII.

1435. Chinese Medicine. By James M. Flint. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 180–182.

1436. Notes on the Rocks of Nugsuaks Peninsula and its Environs, Greenland. By W. C. Phalen. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 183–212, plates LIII–LV.

1440. A Select Bibliography of Chemistry, 1492–1902. By Henry Carrington Bolton. Second Supplement. City of Washington: Published by the Smithsonian Institution, 1904. Octavo. Pages III, 462.

1441. Hodgkins Fund. Researches on the Attainment of Very Low Temperatures. By Morris W. Travers. Part I. City of Washington: Published by the Smithsonian Institution, 1904. Octavo. Pages I, 32, text figures 1–11.

1445. Smithsonian Miscellaneous Collections, Vol. XLV. (Quarterly Issue, Vol. I, parts 3 and 4, October–December, 1903.) City of Washington: Published by the Smithsonian Institution, 1904. Pages XII, 225–463, plates LVII–CIII, text figures 29–45.

1446. A Method of Avoiding Personal Equation in Transit Observations. By S. P. Langley. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 225–229, plates LVII.

1447. On a Collection of Fishes made by Mr. Alan Owston in the Deep Waters of Japan. By David Starr Jordan and John Otterbein Snyder. Reprinted from Smith-

sonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 230–240, plates LVIII–LXIII, text figure 29.

1448. Description of New Cyprinoid Fish, Hemibarbus Joiteni, from the Pei Ho, Tientsin, China. By David Starr Jordan and Edwin Chapin Starks. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 241–242, plate LXIV.

1449. The Removal of the Remains of James Smithson. By S. P. Langley. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 243–251, text figure 30.

1450. Notes on the Breeding Habits of the Yellow-bellied Terrapin. By Hugh M. Smith. Reprinted from the Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 252–253.

1451. A New Pelican Fish from the Pacific. By Barton A. Bean. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 254–255, text figure 31.

1452. A Revision of the Paleozoic Bryozoa. Part I. Ctenostomata. By E. O. Ulrich and R. S. Bassler. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 256–294, plates LXV–LXVIII, text figures 32–33.

1453. A Remarkable Genus of Fishes, the Umbras. By Theodore Gill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 295–305, text figures 34–38.

1454. A New Occurrence of Unakite. By W. C. Phalen. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 306–316, plates LXIX–LXXI.

1455. The Dinosaur Trachodon Annectens. By F. A. Lucas. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 317–320, plates LXXII–LXXIII, text figures 40–43.

1456. Classification of the Hares and their Allies. By Marcus Ward Lyon, jr. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLV. Pages 321–447, plates LXXIV–C, text figures 44–45.

7. Smithsonian Miscellaneous Collections, Vol. XLV (containing Quarterly Issue, Vol. I, Parts 1–4). 1904.

Several other works for the series of Miscellaneous Collections are in press, including a Catalogue of North American Diptera, by Prof. J. M. Aldrich, and Researches in Helmintnology and Parasitology, by Dr. Joseph Leidy.

III. SMITHSONIAN ANNUAL REPORTS.

The annual report is in two parts or volumes, one devoted to the Institution proper and the other to the National Museum. The contents of the Smithsonian volume for 1902 were given in the last report of the editor when the work was all in type, although the bound volume and all the separate papers had not then been distributed.

1377. Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1902. Washington: Government Printing Office, 1903. Octavo. Pages LVI, 687; 114 plates, 59 text figures.

Additional copies of several papers from the annual reports of previous years were printed to supply continued demands. These included:

1443. On the Various Modes of Flight in Relation to Aeronautics. By Dr. James Bell Pettigrew. From the Smithsonian Report for 1867, pages 325–334. Washington: 1904.

The Secretary's report for the year ending June 30, 1903, was put in type in November, 1903, for the use of the Regents. The General Appendix of the 1903

volume was sent to the Public Printer in May, 1904, and most of it had been put in type before the fiscal year closed. The contents of this report are as follows:

1520. Experimental Studies in the Mental Life of Animals. By N. Vaschide and P. Rosseau. Pages 545–566.

1521. Animals that Hunt. By Henri Coupin. Pages 567–571.

1522. Flamingoes' Nests. By Frank M. Chapman. Pages 573–575, plates I–II.

1523. Upon Maternal Solicitude in Rhynchota and Other Nonsocial Insects. By G. W. Kirkaldy. Pages 577–585.

1524. The Psychical Faculties of Ants and Some Other Insects. By A. Forel. Pages 587–599.

1525. Musk Oxen in Captivity. By Jul. Schiött. Pages 601–609, plates I–IV.

1526. Frozen Mammoth in Siberia. By O. F. Herz. Pages 611–625, plates I–IX.

1527. Spouting and Movements of Whales. By E. C. Racovitza. Pages 627–645.

1528. Problems Arising from Variations in the Development of Skull and Brains. By Prof. Johnson Symington. Pages 647–660.

1529. The Antiquity of the Lion in Greece. By Dr. A. B. Meyer. Pages 661–667, plate I.

1530. The Excavations at Abusir, Egypt. By Dr. A. Wiedemann. Pages 669–680 plates I–VIII.

1531. The Ancient Hittites. By Dr. Leopold Messerschmidt. Pages 681–703, plates I–VI.

1532. Central American Hieroglyphics. By Cyrus Thomas. Pages 705–721, plates I–III.

1533. Traces of Aboriginal Operations in an Iron Mine Near Leslie, Mo. By W. H. Holmes. Pages 723–726, plates I–VII.

1534. Lhasa and Central Tibet. By G. Ts. Tsybikoff. Pages 727–746, plates I–VII.

1535. A Journey of Geographical and Archæological Exploration in Chinese Turkestan. By M. A. Stein. Pages 747–774, plates I–VII.

1536. From the Somali Coast through Ethiopia to the Sudan. By Oscar Neumann. Pages 775–792, plates I–VI.

1537. Primeval Japanese. By Capt. F. Brinkley. Pages 793–804.

1538. The Korean Language. By Homer B. Hulbert. Pages 805–810.

1539. The Republic of Panama. By Prof. William H. Burr. Pages 811–826, plates I–II.

1540. The Reclamation of the West. By F. H. Newell. Pages 827–841, plates I–IV.

1541. Robert Henry Thurston. By W. F. Durand. Pages 843–849, plate I.

1542. Theodore Mommsen. By Emil Reich. Pages 851–855.

IV. SPECIAL PUBLICATIONS OF SMITHSONIAN INSTITUTION.

1418. International Exchange List of the Smithsonian Institution, September, 1903. Pages 492.

1442. James Smithson. By Samuel Pierpont Langley. (Reprinted from The Smithsonian Institution, 1846–1896. The History of its First Half Century.) City of Washington, 1904. Octavo. Pages 25; portrait of Smithson.

1460. International Exchange. Brussels Convention of 1886, Proclaimed by the United States, 1889.

1461. Classified list of Smithsonian publications available for distribution April, 1904. Pages 29.

V. NATIONAL MUSEUM PUBLICATIONS.

The publications of the National Museum consist (*a*) the Annual Report, forming a separate volume of the Report of the Smithsonian Institution; (*b*) The Proceedings of the United States National Museum; (*c*) the Bulletin of the United States National Museum, and (*d*) Contributions from the United States Herbarium.

The Report for the year ending June 30, 1902, was completed during the past fiscal year and the manuscript of the 1903 Report was in press.

1416. Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1902. Report of the United States National Museum. Washington: Government Printing Office, 1904. Octavo. Pages XXIV, 784, plates 1–248, 1, 1–13; text figures, 1–212, 1–197.

CONTENTS.

Proceedings of the United States National Museum. Volume XXV. Published under the direction of the Smithsonian Institution. Washington: Government Printing Office, 1903. Octavo. Pages XIV, 1021, with text figures and 32 plates.

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No. 1333. Notes on Orthoptera from Colorado, New Mexico, Arizona, and Texas, with descriptions of new species. By Andrew Nelson Caudell. Pages 775–809, plate LV.

No. 1334. A review of the Cyprinoid fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 811–862, text figures 1–8.

No. 1335. The Phasmidæ or walking sticks of the United States. By Andrew Nelson Caudell. Pages 863–885, plates LVI–LIX.

No. 1336. Description of an extinct mink from the shell heaps of the Maine coast. By Daniel Webster Prentiss. Pages 887–888, text figure.

No. 1337. Revision of the Crustacea of the genus Lepidopa. By James E. Benedict. Pages 889–895, text figures 1–8.

No. 1338. A review of the Siluroid fishes or Catfishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 897–911, text figures 1–2.

No. 1339. Notice of a collection of fishes made by H. H. Brimley in Cane River and Bollings Creek, North Carolina, with a description of a new species of Notropis (*N. brimleyi*). By Barton A. Bean. Pages 913–914.

No. 1340. On the relations of the fishes of the family Lamprididæ or Opahs. By Theodore Gill. Pages 915–924, text figures 1–3.

No. 1341. Amphipoda from Costa Rica. By Rev. Thomas R. R. Stebbing. Pages 925–931, plates LX–LXI.

No. 1342. Synopsis of the family Astartidæ, with a review of the American species. By William Healey Dall. Pages 933–951, plates LXII–LXIII.

No. 1343. An Alaskan corymorpha-like Hydroid. By Samuel Fessenden Clarke. Pages 953–958, text figures 1–7.

No. 1344. On some neglected genera of fishes. By Theodore Gill. Pages 959–962.

No. 1345. Notice of a small collection of fishes, including a rare eel, recently

received from H. Maxwell Lefroy, Bridgetown, Barbados, West Indies. By Barton A. Bean. Pages 963–964, text figure.

No. 1346. On some fish genera of the first edition of Cuvier's Règne Animal and Oken's Names. By Theodore Gill. Pages 965–967.

No. 1347. Report on the fresh-water Ostracoida of the United States National Museum, including a revision of the subfamilies and genera of the family Cyprididæ. By Richard W. Sharpe. Pages 965–1001, plates LXIV–LXIX.

No. 1348. A review of the fishes of Japan belonging to the family of Hexagrammidæ. By David Starr Jordan and Edwin Chapin Starks. Pages 1003–1013, text figures 1–3.

No. 1349. Note on the fish genera named Macrodon. By Theodore Gill. Pages 1015–1016.

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No. 1350. Contributions to the Natural History of the Isopoda. By Harriet Richardson. Pages 1–89, text figures 1–92.

No. 1351. A review of the Scorpænoid fishes of Japan. By David Starr Jordan and Edwin Chapin Starks. Pages 91–175, plates I–II, text figures 1–20.

No. 1352. A revision of the American great horned owls. By Harry C. Oberholser. Pages 177–192.

No. 1353. A new batrachian and a new reptile from the Trias of Arizona. By Frederic A. Lucas. Pages 193–195, plates III–IV.

No. 1354. A review of the wrens of the genus Troglodytes. By Harry C. Oberholser. Pages 197–210, plate V.

No. 1355. Report on the fresh-water Bryozoa of the United States. By Charles B. Davenport. Pages 211–221, plate VI.

No. 1365. On the species of White Chimera from Japan. By David Starr Jordan and John Otterbein Snyder. Pages 223–226, text figures 1–2.

No. 1357. Notes on a killer whale (genus Orcinus) from the coast of Maine. By Frederick W. True. Pages 227–230, plates VII–VIII.

No. 1358. A review of the Cottidæ or Sculpins found in the waters of Japan. By David Starr Jordan and Edwin Chapin Starks. Pages 231–335, text figures 1–43.

No. 1359. Notes on the bats collected by William Palmer in Cuba. By Gerrit S. Miller, jr. Pages 337–348. Plate IX.

No. 1360. List of Hemiptera-Heteroptera of Las Vegas Hot Springs, New Mexico. Collected by Messrs. C. A. Schwarz and Herbert S. Barber. Pages 349–364.

No. 1361. A revision of American Siphonaptera, or fleas, together with a complete list and bibliography of the group. By Carl F. Baker. Pages 365–469, plates X–XXVI.

No. 1362. The Aleyrodids, or mealey-winged flies, of California, with references to other American species. By Florence E. Bemis. Pages 471–537, plates XXVII–XXXVII.

No. 1363. Studies in Old World Forficulids or earwigs, and Blattids or cockroaches. By James A. G. Rehn. Pages 539–560.

No. 1364. Studies in American Mantids or soothsayers. By James A. G. Rehn. Pages 561–574.

No. 1365. A review of the Japanese fishes of the family of Agonidæ. By David Starr Jordan and Edwin Chapin Starks. Pages 575–599, text figures 1–13.

No. 1366. The osteology of some Berycoid fishes. By Edwin Chapin Starks. Pages 601–619, text figures 1–10.

No. 1367. A new genus and two new species of Crustaceans of the family Albuneidæ from the Pacific Ocean; with remarks on the probable use of the antennulæ in Albunea and Lepidopa. By James E. Benedict. Pages 621–625, text figures 1–5.

No. 1368. A new species of Argulus, with a more complete account of two species already described. By Charles Branch Wilson. Pages 627–655, text figures 1–38.

No. 1369. Contributions to the Natural History of the Isopóda. By Harriet Richardson. Pages 657–681, text figures 1–39.

No. 1370. Description of a new African weaver-bird. By Harry C. Oberholser. Page 683.

No. 1371. New dragon-fly nymphs in the United States National Museum. By James G. Needham. Pages 685–720, plates XXXVIII–XLIV, text figures 1–11.

No. 1372. New molluscan genera from the Carboniferous. By George H. Girty. Pages 721–736, plates XLV–XLVII.

No. 1373. Descriptions of two new birds from Somali Land. By Harry C. Oberholser. Pages 737–739.

No. 1374. Two new ferns of the genus Polypodium, from Jamaica. By William R. Maxon. Pages 741–744.

No. 1375. Tineid moths from British Columbia, with descriptions of new species. By August Busck. Pages 745–778.

No. 1376. The Lepidoptera of the Kootenai District of British Columbia. By Harrison G. Dyar. Pages 779–938.

No. 1377. Notes on collections of fishes from Oahu Island and Laysan Island, Hawaii, with descriptions of four new species. By David Starr Jordan and John Otterbein Snyder. Pages 939–948.

No. 1378. Two Orthoptera hitherto unrecorded from the United States. By Andrew Nelson Caudell. Pages 949–952, text figures 1–3.

No. 1379. A new fern, Goniophlebium pringlei, from Mexico. By William R. Maxon. Pages 953–954, plate XLVIII, text figure.

No. 1380. The Persimmon Creek Meteorite. By Wirt Tassin. Pages 955–959, plates XLIX–L.

No. 1381. Schmidtina, a genus of Japanese sculpins. By David Starr Jordan and Edwin Chapin Starks. Page 961.

VI. ASTROPHYSICAL OBSERVATORY.

No. 1439. The 1900 Solar Eclipse Expedition of the Astrophysical Observatory of the Smithsonian Institution. By S. P. Langley, aided by C. G. Abbot. Washington: Government Printing Office, 1904. Quarto. Pages 26, plates I–XXII.

VII. BUREAU OF AMERICAN ETHNOLOGY.

Twentieth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1898–99. By J. W. Powell, Director. Washington: Government Printing Office. 1903. Large octavo. Pages CCXXIV, 237. Plates 1–177 and 79 text figures.

CONTENTS: Administrative report of Director. Aboriginal Pottery of the United States by W. H. Holmes.

Twenty-second Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1900–1901. By J. W. Powell, Director. In two parts. Part I. Washington: Government Printing Office. 1904. Pages XLIV, 320. Plates I–XCI and 181 text figures.

CONTENTS: Two summers' work in Pueblo ruins, by Jesse Walter Fewkes. Mayan Calendar Systems, II, by Cyrus Thomas.

VIII. REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual report of the American Historical Association for the year 1903 was received and transmitted to the printer in May, 1904. Its contents are as follows:

Volume I.

Report of Proceedings of Nineteenth Annual Meeting, at New Orleans, December 29-31, 1903, by Charles H. Haskins, corresponding secretary.

Ethical Values in History, by Henry Charles Lea.

Compromises of the Constitution, by Max Farrand.

The World Aspects of the Louisiana Purchase, by William M. Sloane.

The Story of Lewis and Clark's Journals, by Reuben Gold Thwaites.

The Aaron Burr Conspiracy at New Orleans, by Walter Flavius McCaleb.

The Spanish Archives and their Importance for the History of the United States, by William R. Shepherd.

The American Colonial Charter, by Louise Phelps Kellogg.

Public Documents of the First Fourteen Congresses, by Gen. A. W. Greely.

Report of Public Archives Commission.

Volume II.

Seventh Report of Historical Manuscript Commission. Correspondence of the French Ministers to the United States, 1791-1797.

IX. REPORT OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The sixth report of the National Society of the Daughters of the American Revolution was received from that Society in May and submitted to Congress.

Respectfully submitted.

A. HOWARD CLARK, *Editor.*

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Appendix VIII.

REPORT OF THE REPRESENTATIVE OF THE SMITHSONIAN INSTITUTION AND NATIONAL MUSEUM, LOUISIANA PURCHASE EXPOSITION, ST. LOUIS, MO., 1904.

Sir: I have the honor to submit the following report on the Louisiana Purchase Exposition held at St. Louis, Mo., from April 30 to December 1, 1904, inclusive:

An act of Congress approved June 28, 1902, provided for a Government exhibit to be made by the several Executive Departments, bureaus, and other organizations, including the Smithsonian Institution and National Museum, under the management of a Government board. The sum of $800,000 was appropriated for this exhibit, and for buildings the sum of $450,000.

The main Government building, containing a floor space of 102,000 square feet, was located on an eminence at the east end of the Exposition grounds. Adjoining it was a smaller building for the aquarium and other exhibits of the United States Commission of Fish and Fisheries, and at a short distance farther south was erected a large cage for the exhibits of the National Zoological Park. A building and inclosure for the exhibit of the Life-Saving Service were located in another part of the grounds.

Congress subsequently appropriated the sum of $100,000 for an exhibit of the agricultural and experiment stations and colleges of mechanic arts. This exhibit was placed in the education building.

The principal embellishment of the interior of the Government building was a reproduction of the Statue of Liberty, by Crawford, which surmounts the dome of the Capitol. The replica was made in staff by Mr. U. S. J. Dunbar from the original model in the rotunda of the National Museum.

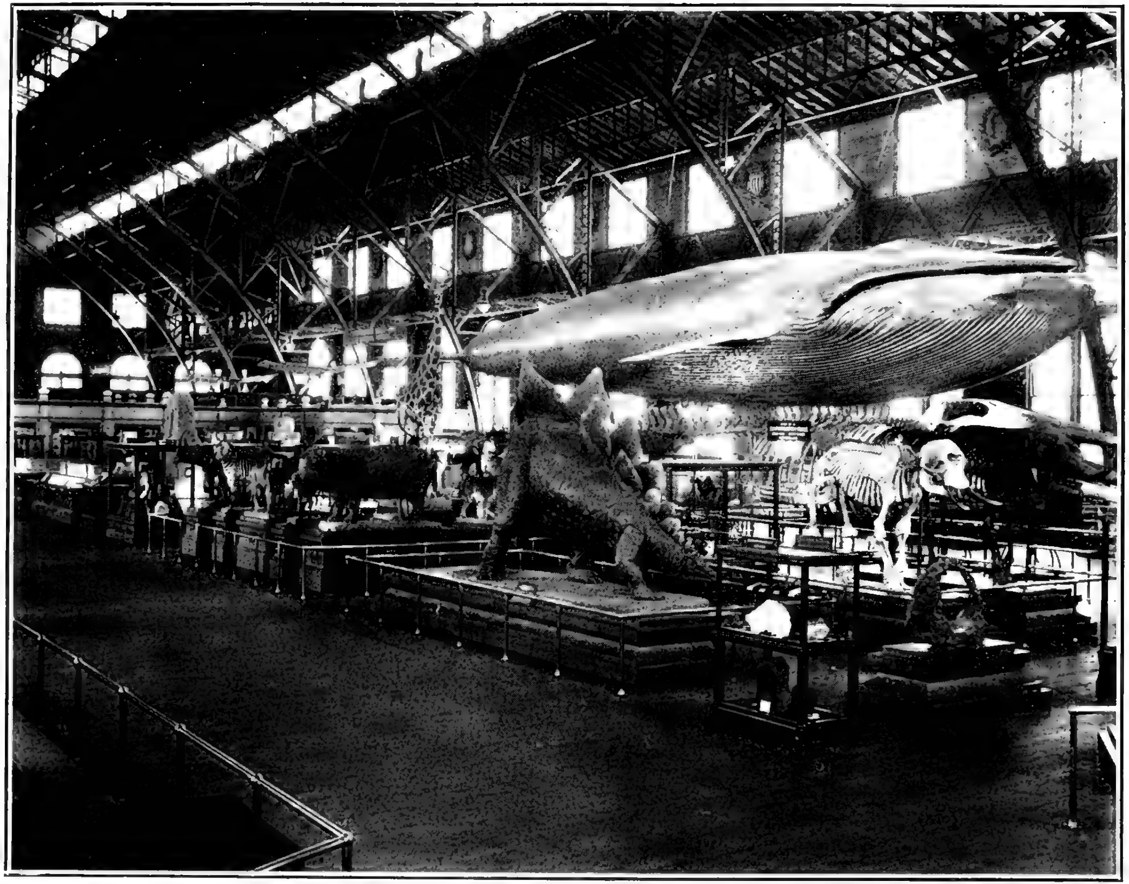
The space in the Government building assigned to the Smithsonian Institution and National Museum comprised about 16,500 square feet, having a frontage on the main aisle of a little over 200 feet and a depth of about 77 feet. It was located on the south side of the building, beginning at the rotunda and adjoining the space of the Post-Office Department at the farther end.

One end of this space was occupied by a specially designed pavilion 77 feet long and 25 feet wide, containing the exhibits of the Smithsonian Institution proper (including the Hodgkins fund), the Bureau of International Exchanges, and the Astrophysical Observatory, as well as a representation of the Children's Room in the Smithsonian building at Washington. The remainder of the space was occupied by the exhibit of the National Museum and that of the Bureau of American Ethnology.

In addition to the space in the Government building, an area outside, about 100 by 300 feet and lying 100 or 200 yards south of the building, as already stated, was assigned to the exhibit of the National Zoological Park, consisting of a large flying cage for birds.

A large coelostat, which constituted a part of the exhibit of the Astrophysical Observatory, was also placed outside the Government building, about 30 feet south, opposite the east end of the Smithsonian space, a brick pier being erected as a foundation.

The allotment of funds to the Institution and Museum from the appropriation for a Government exhibit was $110,000.



GENERAL VIEW OF THE ST. LOUIS EXHIBIT OF THE SMITHSONIAN INSTUTITION AND NATIONAL MUSEUM FROM THE MAIN AISLE, LOOKING NORTH.

GENERAL VIEW OF THE ST. LOUIS EXHIBIT OF THE NATIONAL MUSEUM. CENTER AISLE, LOOKING NORTH TOWARD THE SMITHSONIAN PAVILION.

SMITHSONIAN INSTITUTION PROPER.

The exhibit of the Smithsonian Institution occupied a space of about 625 square feet in the central court of the pavilion mentioned above. A special table case was placed in the middle of this court in which were displayed copies of the History of the First Half Century of the Smithsonian Institution, the seal of the Institution, and several Hodgkins medals. A continuous seat extended along the east wall of the court, above which were displayed two portraits of James Smithson, copies of his scientific papers, a cast of the bronze tablet which was placed on his tomb at Genoa, Italy, and pictures of the tomb itself. Adjoining these objects was a series of photographs of the chancellors and regents of the Institution and portraits of the secretaries. On the south wall of the court was exhibited a portrait of Thomas G. Hodgkins and circulars and papers relating to the Hodgkins fund. A portion of the north wall of the court was occupied by an exhibit from the Bureau of International Exchanges, consisting of a large statistical chart, showing its operations for a period of fifty-three years. A complete series of the publications of the Institution and all its dependencies, comprising 278 volumes, was also exhibited in this space. Hung in midair over the pavilion was the quarter-size model of the Langley gas-driven aerodrome of 1904. The Langley steam-driven aerodrome of 1896 was also hung in midair about 30 feet in front of the former. Three enlarged photographs of the steam-driven aerodrome when in motion were hung on the side-walls of the pavilion.

The Children's Room occupied the portion of the pavilion abutting on the main aisle. In shape, size, and character of fittings and exhibits, the room was, as nearly as possible, a replica of the original room in the Smithsonian building. Around the walls were specially constructed low cases of light-colored wood, while in the center of the room, on a low stand, was an aquarium, and near by a cage of living song-birds. A portion of the wall-case was occupied by birds of interest to children, among which were the following: Familiar birds of the United States; birds-of-paradise, and others noted for their brilliancy of coloring; interesting water-birds, such as the eider duck, lapwing, avocet, European stork, penguin, barnacle goose; other noteworthy birds, such as the apteryx, rook, jackdaw, and lyre bird, the harpy eagle, the condor, and examples of the largest and smallest owls. In this room were also exhibited the duckbill, or platypus, and the spiny ant-eater, peculiar egg-laying mammals from Australia. To illustrate how animals are protected by their color and form, or "how creatures hide," was shown a weasel in the white winter coat on snow-covered ground, and another in the brown summer coat amid dead leaves; also an underwing moth on bark, and such peculiar insects as the katydid and walking-stick. Curious forms of life were shown in the finger sponge, the glass sponge, the organ-pipe coral, and the sea-horse, as well as brilliantly colored parrot fishes. The room also contained a small exhibit of useful minerals. In the south and east part of the wall-case was a collection of beautiful and interesting shells, including those of the giant clam, *Tridacna*. In another part of the room were some comparative exhibits, such as a cast of the egg of the extinct bird *Epyornis* and the egg of a hummingbird, representing the largest and smallest eggs. Groups of brilliant North American and South American butterflies, and of familiar forms, arranged to show life-histories, were also exhibited.

As a part of the exhibit of the Smithsonian Institution, may be mentioned a descriptive pamphlet of 35 pages and 12 plates, for gratuitous distribution to the public, being an account of the Smithsonian Institution, its origin, history, objects, and achievements.

ASTROPHYSICAL OBSERVATORY.

As already mentioned, this exhibit occupied the south court of the main pavilion, which could be entered only from the court devoted to the Smithsonian proper. At previous expositions, the exhibit of this Bureau consisted of publications, charts of the infra-red spectrum, and other charts relating to astrophysics, some small pieces of apparatus, and a series of transparent photographs of solar eclipses and of sun spots. All these objects were exhibited at St. Louis, and in addition a working exhibit was prepared. This consisted, first, of a bolometer connected with a galvanometer, on which was attached a mirror which threw a spot of light on a horizontal scale, so that any change of temperature in the bolometer would be transmitted to the galvanometer and the spot could be seen to move. This change of temperature could be brought about by a visitor simply holding his hand over a hole in the case in which the bolometer was placed. The whole exhibit was carefully labeled, and there was scarcely a moment during the day when visitors could not be found watching the workings of this delicate instrument for measuring slight changes in temperature.

The other moving exhibit consisted of a large two-mirrored coelostat, specially constructed for this exposition, which, as before mentioned, was located about 30 feet south of the Government building, opposite the court in which the astrophysical exhibit was made. This coelostat on sunny days reflected a large beam of sunlight through a window into a dark room which occupied over half of the astrophysical court. Part of the beam of sunlight was thrown through a telescope, which in turn threw a large image of the sun on the north wall of the dark room. At scarcely any time during the seven months of the exposition was the visitor unable to find large sun-spots, or groups of spots, on this image. Another portion of the beam of light was reflected by a series of mirrors to a grating of speculum metal, which in turn threw a brilliant solar spectrum around the east and south walls of the dark room. To make this exhibit more intelligible to the public, a descriptive illustrated pamphlet, written by the director, was distributed gratuitously to those desiring copies.

NATIONAL ZOOLOGICAL PARK.

At previous expositions the exhibit of the National Zoological Park has consisted of pictures of the buildings and paddocks in the park, with the addition, usually, of a small model of the park itself. It was felt that such a representation of this Bureau at the St. Louis Exposition would be inadequate, and, after a careful consideration of possibilities, an extensive exhibit of birds, placed in a cage large enough to permit them to fly about, was decided upon. The cage was 228 feet long, 84 feet wide, and 50 feet high, and was erected by the Supervising Architect of the Treasury Department at the request of the representative of the Institution from the appropriation for Government buildings, at a cost of about $17,500. This cage, which was designed by the superintendent of the park, was probably the largest of its kind ever built. It was traversed by a central arched passageway, open to the public, extending the entire length of the cage. As already mentioned, the cage was situated 100 or 200 yards south of the main building, in a small valley, amid trees, several of which were inclosed by the cage. It was divided into two portions by a longitudinal partition. In the north half were confined the larger birds, among which were gulls, three species of wild geese, trumpeter swans, Cuban flamingos, roseate spoonbills, four species of ibis, three species of heron, demoiselle cranes, white pelicans, brown pelicans, European pelicans, and other birds, such as darters,

cormorants, curassows, and vultures. In the south half of the cage were placed the smaller birds, such as quails, partridges, doves, ducks, canaries, English blackbirds, jays, thrushes, Javan sparrows, bullfinches, goldfinches, weaver birds, linnets, cardinals, orioles, etc. The exhibit of the National Zoological Park proved one of the most attractive in the exposition grounds, and was surrounded by visitors at all times during the day. The exhibit required the constant attention of two men. The records show that the large fish-eating birds consumed an average daily amount of 40 pounds of fish and 5 pounds of chopped meat, while for the smaller birds large quantities of fresh vegetables, grains, and other seeds were required.

BUREAU OF INTERNATIONAL EXCHANGES.

It will be appreciated that the work of the Bureau of International Exchanges does not lend itself to exhibition by material objects. The exhibit at St. Louis consisted of a large chart showing the number of packages transmitted each year from the establishment of the bureau to the present time. There were also shown photographs of the offices of the bureau in the Smithsonian building. In order to explain more fully the functions and operations of the bureau a small descriptive pamphlet was prepared, copies of which were given to those desiring them.

THE BUREAU OF AMERICAN ETHNOLOGY.

The exhibit of the Bureau of American Ethnology was for the most part incorporated with that of the department of anthropology of the United States National Museum, both of which were under the direction of Mr. W. H. Holmes, chief of the bureau. This exhibit was chiefly illustrative of the symbolic art, decorative designs, and heraldry of the American Indians, and represented the researches of the ethnologists of the bureau. Included with it was a series of objects representing the archaeology of the West Indies. These exhibits were installed in recesses in the front wall of the Smithsonian pavilion, in a portion of the south wall case, and in two large floor cases. Further notice of this exhibit and of the special significance of the various objects shown will be found on pages 47 to 49 of this report. A considerable amount of field-work was done in this connection by Messrs. Fewkes, Swanton, and Mooney, and Mrs. Stevenson, ethnologists of the bureau, notice of which will be found in the place mentioned.

THE NATIONAL MUSEUM.

As at all previous expositions, the largest display was made by the National Museum, owing to its special function and its opportunities for making large exhibits. The floor-space not occupied by the bureaus already mentioned was roughly divided into three portions, one devoted to each of the three executive departments of the Museum—namely, anthropology, biology, and geology.

The Department of Anthropology.—This exhibit was planned by Mr. W. H. Holmes, chief of the Bureau of Ethnology, assisted by the curators of the department of anthropology. The main theme of this exhibit was the esthetic achievements of the native American peoples. In conjunction therewith, some of the works of art of ancient civilizations of the Old World were shown.

The carvings of the American Indians were represented by such objects as stone and wooden masks, carved boxes, benches, horns, weapons, etc. These were installed in a special black floor-case. The larger carvings included four house-panels of the Tlinkit Indians and two large house-posts of the Haida Indians. The former were placed on the wall and the latter on the floor. To

these were added two large totem poles, which, owing to lack of space, as well as on account of their large size, were set up out-of-doors, in front of the Indian school building, at the opposite end of the exposition grounds.

The exhibit of textile arts represented the work of tribes of the Northwest, those of the Pueblo region, and the Indians of Central and South America. Among the latter were examples of the beautiful woven garments found in the ancient cemetery at Ancon, Peru. In a portion of one of the cases containing the textile arts were specimens of the closely-related feather work of the American Indians, comprising headdresses, wristbands, and other ornaments. This exhibit was installed in two special floor-cases.

The ceramic art was represented by various pieces of pottery of the Indians of North, Central, and South America, which were displayed in a special floor case, while around the top of the Smithsonian pavilion and the top of that part of the wall cases devoted to the Bureau of American Ethnology were placed as decorative objects 29 specimens of Indian pottery.

Another special case was devoted to the basketry of various Indian tribes and contained about 50 baskets of different forms and patterns.

A special floor-case contained objects representing the sculpture of the American Indians, such as idols, yokes, carved animals, tablets, weapons, celts, metates, pipes, etc. Other objects of sculpture, placed on separate pedestals, were a cast of a colossal figure of an Aztec deity from the ancient City of Mexico, a cast of a statue of a Mayan deity from the ruined city of Quirigua, Guatemala, and a cast of an ancient statue from Costa Rica. A sculptured altar-panel from an ancient Mayan temple and ceremonial subjects in relief from a temple at Menche, Mexico, were placed on large screens.

The architecture of the American Indians was represented by complete restorations, on a reduced scale, of five of the ruined temples of the Aztecs of Mexico, namely, the Temple of Xochicalco at Morales, the "Temple of the Cross" at Palenque, the "House of the Governor" at Uxmal, the "Temple of the Columns" at Mitla, and the "Castle" at Chichen-Itza, each placed on a large separate pedestal. These temples were arranged in a group in the center of the space of the department of anthropology. They were built under the immediate direction of Mr. W. H. Holmes by Delancy Gill, architect, and Messrs. H. W. Hendley and W. H. Gill, sculptors. On two large screens near these temples were hung photographs and drawings of the ruined cities in which the originals of these buildings were found.

In the section assigned to anthropology was exhibited an historical collection made by the Society of the Daughters of the American Revolution, whose archives and collections are, by provision of law, deposited in the Smithsonian Institution. A picture of the Continental Hall now being erected in Washington, and portraits of the presidents-general of the society were also shown, together with a small series of objects of historical interest belonging to the Society of the Children of the American Revolution. A portrait of Baron von Closen was also exhibited.

Department of Biology.—The exhibit of this Department was planned by Dr. F. W. True, head curator, assisted by Mr. F. A. Lucas and others of the Museum staff. While illustrating the methods of preparing, arranging, installing, and labeling zoological collections employed in the National Museum, it was designed also with a view of displaying some of the largest, most striking, and most beautiful forms of animal life now existing. On account of the character of the exposition, the exhibit was given a world-wide scope. Many objects were taken from the permanent exhibition-series, and others obtained and prepared especially for this exhibit. Botanical exhibits were omitted for the reason that

CENTRAL COURT, SMITHSONIAN PAVILION, SHOWING PORTRAITS OF JAMES SMITHSON AND OF THE CHANCELLORS, REGENTS, AND SECRETARIES OF THE INSTITUTION.

ENTRANCE TO ST. LOUIS EXHIBIT OF THE ASTROPHYSICAL OBSERVATORY, SHOWING TRANSPARENCIES OF THE TOTAL ECLIPSE OF THE SUN AS OBSERVED AT WADESBORO, N. C., 1900.

the botanical division of the department consists at present practically only of an herbarium, the collections of which it was thought could not be made interesting to the general public.

The most striking feature of the exhibit at St. Louis was the cast of a sulphur-bottom whale, the largest known animal. This large piece was suspended over the central aisle of the Museum space. Placed on the floor near it, was a skeleton of the same species. The cast was obtained through the courtesy of the Cabot Steam Whaling Company, and the skeleton by gift from the Colonial Manufacturing Company, at Balena, Hermitage Bay, Newfoundland, by Messrs. F. A. Lucas, William Palmer, and J. W. Scollick, who made a special expedition to Newfoundland in the spring of 1904 to secure the material.

Another prominent feature of the exhibit of this department comprised a group of 20 game mammals from all parts of the world, namely: From North America, a black bear, a polar bear, an Alaska moose, a Mexican sheep, a Greenland musk-ox, a specimen of Osborn's caribou, and an Olympic elk; from Africa, a giraffe, a zebra, a two-horned rhinoceros, a white-tailed gnu, a hippopotamus, and a lion; from Asia, a tiger, a sambar stag, a specimen of Marco Polo's sheep, an axis deer; from Europe, a chamois, a moufflon or wild sheep, and a Norway elk. Each was placed on a separate pedestal and the whole group inclosed by brass railing.

A small but very popular part of the exhibit of the department was a select collection of birds' eggs, installed in two special table-cases. In one was a series showing variations in size, form, color, and texture, and in the number laid at one time. Among these eggs was one of *Epyornis maximus*, an extinct bird of Madagascar, whose eggs are the largest known. By a fortunate coincidence, an opportunity occurred to purchase a remarkably fine example for addition to this series. Other interesting eggs in this case were those of the apteryx, the great auk, three species of ostrich, several species of tinamou, and the ruby-throated hummingbird. In the second case was placed a very complete collection of the eggs of North American birds of prey.

The main exhibit of birds was installed in four 30-inch screen-cases, and consisted of a series of pheasants especially noteworthy for the brilliancy of their plumage, such as Lady Amherst's pheasant, fire-back pheasants, tragopans, etc. Three species of peafowl were included in this series, each represented by a male and a female. Among the other birds exhibited was a pair of the rare and curious Harris's cormorant, from the Galapagos Islands, a species incapable of flight owing to its dwarfed wings and to the soft, flexible nature of the primary feathers. Installed in a special floor case was a group of hoaczins, *Opisthocomus hoaczin*, showing the life-history of the species. This material of group consisted of 4 adults, 3 nestlings, 2 half-grown young, 2 nests, 2 eggs, together with bushes and other accessories, and was specially collected for exhibition at St. Louis. The young of this singular bird possess well-developed claws on the first and second digits of the wing, by means of which they climb from branch to branch with comparative ease.

Reptiles were represented by mounted specimens of the American crocodile and alligator, which were placed near one another, so that the differences between these two largest of American reptiles could be readily seen. In addition, two special cases of snakes were exhibited; one contained a reticulated python, probably the largest species of snake in existence, and the other a small series of especially noteworthy poisonous and harmless snakes, such as the cobra, the rattlesnake, the harlequin snake, and the king snake.

A unique exhibit of unusual significance and interest consisted of a series of models of deep-sea fishes, installed in two short sections of the wall-case.

These models were based chiefly on specimens in the National Museum, from the rich collections of the U. S. Fish Commission steamer *Albatross.* Owing to the small size of the originals, it was necessary to enlarge the models so that the extraordinary modifications and fantastic appearance of these inhabitants of the deep-sea could be appreciated by the public. Accompanying this series was a diagram showing the great depths at which these peculiar forms are found, in comparison with the other fishes of the sea. The following species were represented: Deep-sea chimæra (*Harriotta raleighana*), hatchet fish (*Sternoptyx diaphana*), rag fish (*Acrotus willoughbyi*), pelican fish (*Gastrostomus bairdii*), snipe eel (*Nemichthys scolopaceus*), lesser angler (*Cryptopsaras couesii*), viper fish (*Chauliodus sloani*), *Bathypterois quadrifilis*, great swallower (*Chiasmodon niger*), deep sea gurnard (*Peristedion miniatum*), and the species *Caulolepis longidens*, *Malacosteus choristodactylus*, and *Malacosteus niger*.

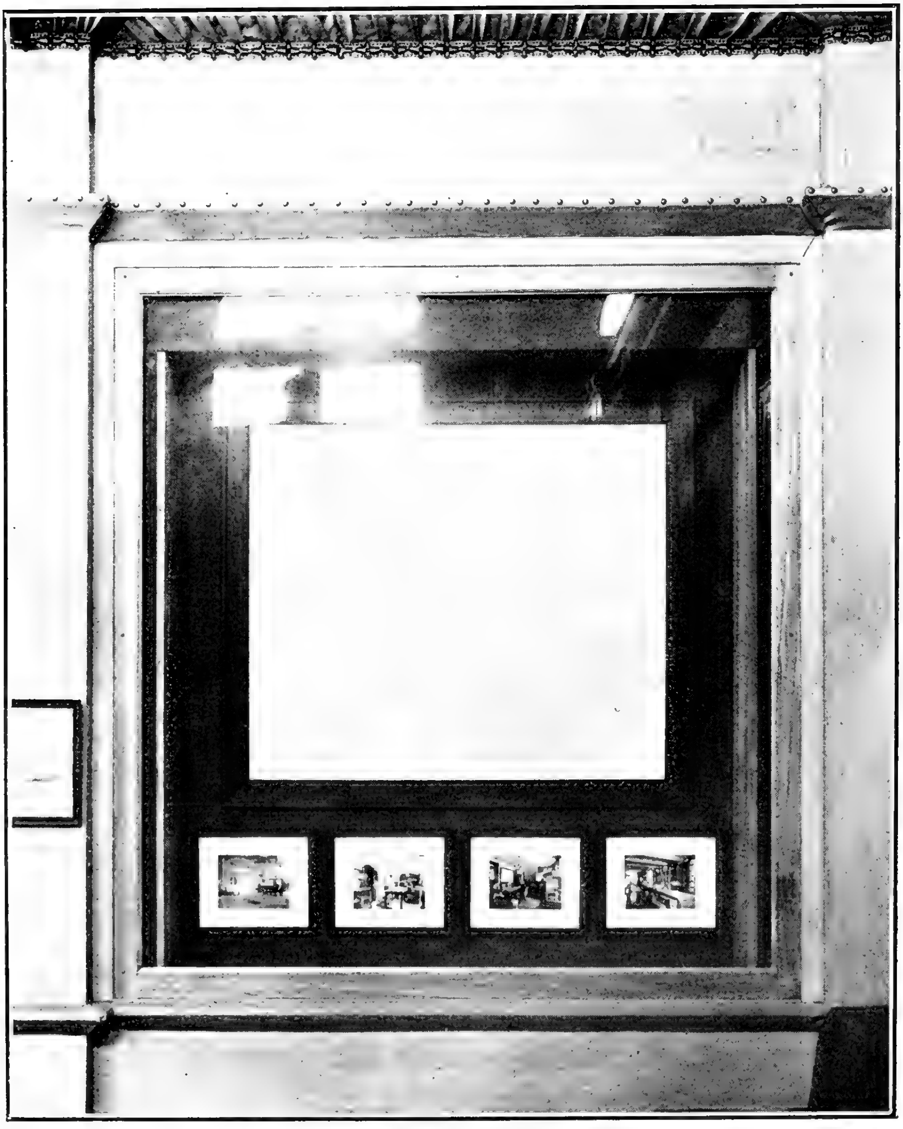
Invertebrates were represented by two series of specimens, installed in standard Museum unit boxes, arranged in frames along the wall. The first was a synoptic series of invertebrates displaying the principal groups, the more important forms in each group, their structure, and, so far as possible, important or interesting features in their life histories. This series was designed especially to show methods of Museum installation. In two sections of the wall case near this series was a special display of fan corals, and another of crabs. The second principal series of invertebrates consisted of about 500 species of butterflies and moths from all parts of the world, selected with special reference to beauty or singularity of color and markings or large size. Each species was represented by a pair of specimens, making about 1,000 in all. The specimens were remarkable for their perfection, and the whole series was, as might be imagined, hardly to be surpassed in brilliancy.

Department of Geology.—The exhibit of this department was planned by Dr. George P. Merrill, head curator, assisted by members of his staff, and embraced four main groups: First, an exhibit of minerals; second, one of meteorites; third, of invertebrate fossils, and, fourth, of vertebrate fossils.

(1) A systematic series of minerals was installed in eight standard 15-inch Museum cases. This series was remarkably complete, and the various species were represented by specimens of the largest size. A complete and particularly fine series of all the known forms of silica occurring in nature was shown in a special 36-inch screen case. This included examples of agates, jasper, wood-opal, etc. In a companion case was exhibited a similar series comprising all the known natural forms of calcium carbonate, such as Iceland spar and other calcites, stalagmites, limestone, pearls, etc. In proximity to the silica exhibit was displayed one of the largest masses of amethyst crystals known, and a giant quartz crystal. The amethyst crystals weighed about a quarter of a ton. Another mineral exhibit consisted of a series of cones from hot springs, showing the deposit of crystals on the interior.

(2) Meteorites: Special pains were taken to assemble an exhibit of meteorites worthy of the occasion. To this end endeavors were made to obtain representations of the largest known examples. Through the courtesy of Commander R. E. Perry, U. S. N., casts were secured of the three great masses from Greenland, known as the "Peary meteorites," and with the concurrence of the Mexican Government and the friendly assistance of José G. Aguilera a cast of the Bacubirito meteorite was also secured. A special trip to Mexico for the purpose of obtaining a mold was undertaken by Dr. George P. Merrill and Mr. William Palmer, with entirely satisfactory results. A cast was also made of the

ST. LOUIS EXHIBIT OF THE NATIONAL ZOOLOGICAL PARK, SHOWING CENTRAL ARCHED PASSAGE IN THE GREAT BIRD CAGE.



ST. LOUIS EXHIBIT OF THE BUREAU OF EXCHANGES. A STATISTICAL CHART AND PHOTOGRAPHS.

Irwin-Ainsa or Tucson meteorite, in the National Museum. These great casts, which include representations of the largest masses which are known to have fallen from the sky, were assembled near the rotunda of the building, and presented a most impressive appearance. Adjacent to the casts was installed a series of actual specimens of meteorites and sections of specimens, and a chart showing the distribution of known meteoric falls, and pictures of falling meteorites.

(3) Vertebrate fossils: The most popular feature of this exhibit was the life-size restoration of an armored dinosaur, known as *Stegasaurus ungulatus*, based on remains from Colorado and Wyoming. The skeleton of the horned dinosaur, *Triceratops*, previously exhibited at Buffalo and Charleston, was also shown at St. Louis. Standing side by side, in order to show their similarity in size and details of structure, were exhibited the skeleton of an American mastodon and that of an African elephant. The skeleton and the cast of an egg of one of the moas (extinct birds from New Zealand) were exhibited in a special case. Other vertebrate fossils were represented by specimens on the slabs of stone in which they were found, embracing fossil fishes, fossil fish-like and crocodile-like reptiles, as well as a very complete specimen of the remarkable flying reptile, *Rhamphorhynchus*, which shows the impress of the wing and tail membranes in the rock.

(4) Invertebrate fossils: These were installed in a section of the wall-case, and comprised cephalopod and other mollusks, including a fine series of ammonites, and crustaceans, crinoids, echinoderms, and corals.

(5) Fossil palm: An opportunity to obtain an exceptionally fine Tertiary fossil palm, *Latanites vicentinus*, having occurred during the preparations for the exposition, the specimen was purchased and added to the geological exhibit. It was obtained in Monte Bolka, province of Verona, Italy.

Dr. F. W. True, representative for the Institution and Museum on the Government board, was also chairman of the committee on installation and decoration. Dr. M. W. Lyon, jr., was chief special agent.

SUMMARY OF ALLOTMENT MADE TO THE SMITHSONIAN INSTITUTION AND NATIONAL MUSEUM.

Original allotment	$110, 000. 00
Transfer to general fund for expenses of United States Marine Band at exposition	300. 00
Net allotment	109, 700. 00

Classified statement of expenditures of funds allotted to the Smithsonian Institution, corrected to January 26, 1905.

Services of clerks, mechanics, and laborers and care of exhibits	$13, 836. 69
Transportation of persons	3, 893. 13
Per diems in lieu of subsistence	7, 604. 50
Freight, cartage, and expressage	3, 252. 43
Cases, including all material, and supplies and labor	15, 920. 26
Packing materials	1, 489. 72
Miscellaneous supplies (stationery, office furniture, janitors' supplies, etc.)	1, 802. 50
Labels (including printing three descriptive pamphlets and painting labels for the exhibit of the National Zoological Park)	2, 398. 03
Rent of shop and construction of shelter for whale cast	655. 19

Specimens and construction of exhibits, including materials, services, field expenses, etc.:

U. S. National Museum—			
Department of Anthropology	$12,847.56		
Department of Biology	19,819.95		
Department of Geology	12,500.94		
		$45,168.45	
Other bureaus of the Institution, including supplies and salaries of keepers for exhibit of National Zoological Park		9,249.03	
			$54,417.48
Total expenditure			105,269.93
Unexpended balance			4,430.07
Net allotment			109,700.00

Respectfully submitted.

F. W. True,

Representative, Smithsonian Institution and United States National Museum, Louisiana Purchase Exposition.

Mr. S. P. Langley,

Secretary of the Smithsonian Institution.

January 26, 1905.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1904.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of pages (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1904.

INSTANTANEOUS PHOTOGRAPH OF THE LAUNCH OF OCTOBER 7, 1903.

EXPERIMENTS WITH THE LANGLEY AERODROME.

By S. P. Langley.

The experiments undertaken by the Smithsonian Institution upon an aerodrome, or flying machine, capable of carrying a man have been suspended from lack of funds to repair defects in the launching apparatus without the machine ever having been in the air at all. As these experiments have been popularly, and of late repeatedly, represented as having failed on the contrary, because the aerodrome could not sustain itself in the air I have decided to give this brief though late account, which may be accepted as the first authoritative statement of them.

It will be remembered that in 1896 wholly successful flights of between one-half and one mile by large steam-driven models, unsupported except by the mechanical effects of steam engines, had been made by me. In all these the machine was first launched into the air from "ways," somewhat as a ship is launched into the water, the machine resting on a car that ran forward on these ways, which fell down at the extremity of the car's motion, releasing the aerodrome for its free flight. I mention these details because they are essential to an understanding of what follows, and partly because their success led me to undertake the experiments on a much larger scale I now describe.

In the early part of 1898 a board, composed of officers of the Army and Navy, was appointed to investigate these past experiments with a view to determining just what had been accomplished and what the possibilities were of developing a large-size man-carrying machine for war purposes. The report of this board being favorable, the Board of Ordnance and Fortification of the War Department decided to take up the matter, and I having agreed to give without compensation what time I could spare from official duties, the Board allotted $50,000 for the development, construction, and test of a large aerodrome, half of which sum was to be available immediately and the remainder when required. The whole matter had previously been laid before the Board of Regents of the Smithsonian Institution, who had authorized me to take up the work and

to use in connection with it such facilities of the Institution as were available.

Before consenting to undertake the construction of this large machine, I had fully appreciated that owing to theoretical considerations, into which I do not enter, it would need to be relatively lighter than the smaller one; and later it was so constructed, each foot of sustaining surface in the large machine carrying nearly the same weight as each foot in the model. The difficulties subsequently experienced with the larger machine were, then, due not to this cause, but to practical obstacles connected with the launching, and the like.

I had also fully appreciated the fact that one of the chief difficulties in its construction would lie in the procuring of a suitable engine of sufficient power and, at the same time, one which was light enough. (The models had been driven by steam engines whose water supply weighed too much for very long flights.) The construction of the steam engine is well understood, but now it would become necessary to replace this by gas engines, which for this purpose involve novel difficulties. I resolved not to attempt the task of constructing the engine myself, and had accordingly entered into negotiations with the best engine builders in this country, and after long delay had finally secured a contract with a builder who, of all persons engaged in such work, seemed most likely to achieve success. It was only after this contract for the engine had been signed that I felt willing to formally undertake the work of building the aerodrome.

The contract with the engine builder called for an engine developing 12 brake horsepower, and weighing not more than 100 pounds, including cooling water and all other accessories, and with the proviso that a second engine, exactly like this first one, would be furnished on the same terms. The first engine was to be delivered before the close of February, 1899, and the frame of the aerodrome with sustaining surfaces, propellers, shafting, rudders, etc., was immediately planned, and now that the engine was believed to be secured, their actual construction was pushed with the utmost speed. The previous experiments with steam-driven models, which had been so successful, had been conducted over the water, using a small house-boat having a cabin for storing the machine, appliances and tools, on top of which was mounted a track and car for use in launching. As full success in launching these working models had been achieved after several years spent in devising, testing and improving this plan, I decided to follow the same method with the large machine, and accordingly designed and had built a house-boat, in which the machine could not only be stored, but which would also furnish space for workshops, and on the top of which was mounted a turntable and track for use in launching from whatever direction the wind might come.

Everything connected with the work was expedited as much as possible with the expectation of being able to have the first trial flight before the close of 1899, and time and money had been spent on the aerodrome, which was ready, except for its engine, when the time for the delivery of this arrived. But now the builder proved unable to complete his contract, and, after months of delay, it was necessary to decrease the force at work on the machine proper and its launching appliances until some assurance could be had of the final success of the engine. During the spring and summer of 1899, while these delays were being experienced in procuring suitable engines, former experiments on superposed wing surfaces were continued, time was found for overhauling the two steam-driven models which had been used in 1896, and the small house boat was rebuilt so that further tests of these small machines might be made in order to study the effect of various changes in the balancing and the steering, equilibrium preserving and sustaining appliances, and the months of June, July, and a portion of August were spent in actual tests of these machines in free flight.

A new launching apparatus following the general plan of the former overhead one, but with the track underneath it, was built for the models, and it was used most successfully in these experiments, more than a dozen flights in succession being made with it, while in every case it worked without delay or accident. As soon as these tests with the models on this underneath launching apparatus were completed, that for the large machine was built as an exact duplicate, except for the enlargement, and with some natural confidence that what had worked so perfectly on a small scale would work fairly on a large one.

It was recognized from the very beginning that it would be desirable in a large machine to use "superposed" sustaining surfaces (that is, with one wing above another) on account of their superiority so far as the relation of strength to weight is concerned, and from their independence of guy wiring; and two sets of superposed sustaining surfaces of different patterns were built and experimented with in the early tests. These surfaces proved, on the whole, inferior in lifting power, though among compensating advantages are the strength of a "bridge" construction which dispenses with guy wires coming up from below, which, in fact, later were the cause of disaster in the launching.

It was finally decided to follow what experiment had shown to be successful, and to construct the sustaining surfaces for the large machine after the "single-tier" plan. This proved to be no easy task, since in the construction of the surfaces for the small machines the main and cross ribs of the framework had been made solid, and, after steaming, bent and dried to the proper curvature, while it was

obvious that this plan could not be followed in the large surfaces on account of the necessity, already alluded to, of making them relatively lighter than the small ones, which were already very light. After the most painstaking construction, and tests of various sizes and thicknesses of hollow square, hollow round, I-beam, channel, and many other types of ribs, I finally devised a type which consisted of a hollow box form, having its sides of tapering thickness, with the thickest part at the point midway between contiguous sides and with small partitions placed inside every few inches in somewhat the same way that nature places them in the bamboo. These various parts of the rib (corresponding to the quill in a wing) were then glued and clamped together, and after drying were reduced to the proper dimensions and the ribs covered with several coats of a special marine varnish, which it had been found protected the glued joints from softening, even when they were immersed in water for twenty-four hours.

Comparative measurements were made between these large cross ribs, 11 feet long, and a large quill from the wing of a harpy eagle, which is probably one of the greatest wonders that nature has produced in the way of strength for weight. These measurements showed that the large, 11-foot ribs ("quills") for the sustaining surfaces of the large machine were equally as strong, weight for weight, as the quill of the eagle; but much time was consumed in various constructions and tests before such a result was finally obtained.

During this time a model of the large machine, one-fourth of its linear dimensions, was constructed, and a second contract was made for an engine for it. The delay with the large engine was repeated with the small one, and in the spring of 1900 it was found that both contract engines were failures for the purpose for which they were intended, as neither one developed half of the power required for the allotted weight.

I accordingly again searched all over this country, and, finally, accompanied by an engineer (Mr. Manly), whose services I had engaged, went to Europe, and there personally visited large builders of engines for automobiles, and attempted to get them to undertake the construction of such an engine as was required. This search, however, was fruitless, as all of the foreign builders, as well as those of this country, believed it impossible to construct an engine of the necessary power and as light as I required (less than 10 pounds to the horsepower without fuel or water). I was therefore forced to return to this country and to consent most reluctantly, even at this late date, to have the work of constructing suitable engines undertaken in the shops of the Smithsonian Institution, since, as I have explained, the aerodrome frame and wings were already constructed. This work upon the engines began here in August, 1900, in the immediate care

of Mr. Manly. These engines were to be of nearly double the power first estimated and of little more weight, but this increased power and the strain caused by it demanded a renewal of the frame as first built, in a stronger and consequently in a heavier form, and the following sixteen months were spent in such a reconstruction simultaneously with the work on the engines.

The flying weight of the machine complete, with that of the aeronaut, was 830 pounds; its sustaining surface, 1,040 square feet. It therefore was provided with slightly greater sustaining surface and materially greater relative horsepower than the model subsequently described which flew successfully. The brake horsepower of the engine was 52; the engine itself, without cooling water, or fuel, weighed approximately 1 kilogram to the horsepower. The entire power plant, including cooling water, carburetor, battery, etc., weighed materially less than 5 pounds to the horsepower. Engines for both the large machine and the quarter-size model were completed before the close of 1901, and they were immediately put in their respective frames and tests of them and their power-transmission appliances were begun.

It is well here to call attention to the fact that although an engine may develop sufficient power for the allotted weight, yet it is not at all certain that it will be suitable for use on a machine which is necessarily as light as one for traversing the air, for it would be impossible to use, for instance, a single cylinder gasoline engine in a flying machine unless it had connected to it prohibitively heavy flywheels. These facts being recognized, the engines built in the Smithsonian shops were provided with five cylinders, and it was found upon test that the turning effect received from them was most uniform, and that, by suitable balancing of rotating and reciprocating parts, they could be made to work so that there was practically no vibration, even when used in the very light frames of the aerodromes.

The engine is not all the apparatus connected with the development and delivery of power, for obviously there must be shafts, bearings, and in the present case there were also gears; and all of these parts must necessarily be phenomenally light, while all of the materials must be capable of withstanding repeated and constant strains far beyond their elastic limit. It is also evident to anyone having familiarity with such constructions that it is most difficult to keep the various bearings, shafts, gears, etc., in proper alignment without adding excessive weight, and also that when these various parts once get out of alignment when subject to strain, the disasters which are caused render them unfit for further use.

The engines themselves were successfully completed before the close of 1901, and were of much more power than those originally designed; but nearly a year and a half had been spent not only in their comple-

tion, but in properly coordinating the various parts of the frame carrying them, repairing the various breakages, assembling, dismounting, and reassembling the various parts of the appliances, and in general rebuilding the frame and appurtenances to correspond in strength to the new engines.

There are innumerable other details, for the whole question is one of details. I may, however, particularly mention the carburetors, which form an essential part of every gas engine, and such giving fair satisfaction for use in automobiles were on the market at the time, yet all of them failed to properly generate gas when used in the tests of the engine working in the aerodrome frame, chiefly because of the fact that the movement of the engine in this light frame must be constant and regular or the transmission appliances are certain of distortion. It was, therefore, necessary to devise carburetors for the aerodrome engines which would meet the required conditions, and more than half a dozen were constructed which were in advance of anything then on the market, and yet were not good enough to use in the aerodrome, before a satisfactory one was made. These experiments were made in the shop, but with an imitation of all the disturbing influences which would be met with in the actual use of the machine in the air, so as to make certain, as far as possible, that the first test of the machine in free flight would not be marred by mishaps or unseen contingencies in connection with the generation and use of power.

It is impossible for anyone who has not had experience with such matters to appreciate the great amount of delay which experience has shown is to be expected in such experiments. Only in the spring of 1903, and after two unforeseen years of assiduous labor, were these new engines and their appurtenances, weighing altogether less than 5 pounds to the horsepower and far lighter than any known to be then existing, so coordinated and adjusted that successive shop tests could be made without causing injury to the frame, its bearings, shafts, or propellers.

And now everything seemed to be as nearly ready for an experiment as could be, until the aerodrome was at the location at which the experiments were to take place. The large machine and its quarter-size counterpart were accordingly placed on board the large house boat, which had been completed some time before and had been kept in Washington as an auxiliary shop for use in the construction work, and the whole outfit was towed to a point in the Potomac River, here 3 miles wide, directly opposite Widewater, Va., and about 40 miles below Washington and midway between the Maryland and Virginia shores, where the boat was made fast to moorings which had previously been placed in readiness for it.

Although extreme delays had already occurred, yet they were not

so trying as the ones which began immediately after the work was thus transferred to the lower Potomac.

The object in constructing the quarter-size counterpart of the large machine was to duplicate in it the balancing and relative proportions of power, surface, etc., that had been arranged in the large one, so that a test of it might be made which would determine whether the large machine should be tried as arranged or the balancing and other arrangements modified. The launching apparatus, which had proved so eminently successful with the original steam-driven models in 1896, was considered a thing so well tested that it had, as I have stated, been duplicated on a suitable scale for use with the large aerodrome, and it was felt that if this apparatus were exactly similar to the smaller one it would be the one appliance least likely to mar the experiments.

In order to test the quarter-size model it was necessary to remove its launching track from the top of the small house boat and place it upon the deck of the large boat, in order to have all the work go on at one place, as it was impossible, on account of its unseaworthiness, to moor the small house boat in the middle of the river.

While this transfer of the launching apparatus from the small boat to the large one was being made, the changed atmospheric conditions incident to a large body of water over which thick fogs hung a great portion of the time, from those of a well-protected shop on the land, began to manifest themselves in such ways as the rusting of the metal parts and fittings, and the consequent disarrangement of the adjustment of the necessarily very accurate pieces of apparatus connected with the ignition system of the engine. These difficulties might have partly been anticipated, but there were others concerning which the cause of the deterioration and disarrangement of certain parts and adjustments was not immediately detected, and consequently when short preliminary shop tests of the small machine were attempted just prior to launching it, it was found that the apparatus did not work properly, necessitating repairs and new constructions and consequent delay. Although the large house boat with the entire outfit had been moved down the river on July 14, 1903, it was not until the 8th of August that the test of the quarter-size model was made, and all of this delay was directly due to changed atmospheric conditions incident to the change in locality. This test of the model in actual flight was made on the 8th of August, 1903, when it worked most satisfactorily, the launching apparatus, as always heretofore, performing perfectly, while the model, being launched directly into the face of the wind, flew directly ahead on an even keel. The balancing proved to be perfect, and the power, supporting surface, guiding, and equilibrium-preserving effects of the rudder also. The

weight of the model was 58 pounds, its sustaining surface 66 square feet, and the horsepower from 2½ to 3.

This was the first time in history, so far as I know, that a successful flight of a mechanically sustained flying machine was made in public.

The flight was not as long as had been expected, as it was found afterwards that one of the workmen, in his zeal to insure an especially good one, had overfilled the gasoline tank, which would otherwise have enabled a flight several times as long. However, as such a flight would have given absolutely no more data than the short one did, and as the delays in getting ready for testing the large machine had already far exceeded what was expected, it was thought best not to make any more tests with the small one, as all of the data which was desired had been procured, and it was accordingly stored away and every energy immediately concentrated in getting the large machine ready for its first test, which at that time seemed only a few days away.

During all these delays it may be remarked that we necessarily resided near the house boat, and therefore in a region of malaria, from whose attacks a portion of us suffered.

I have spoken of the serious delays in the test of the small machine caused by changed atmospheric conditions, but they proved to be almost negligible compared with what was later experienced with the large one. I have also alluded to the fact that the necessarily light ribs of the large sustaining wing surfaces were covered with several coats of a special marine varnish which many tests had shown enabled the glue to withstand submersion in water for more than twenty-four hours without being affected. This water test was made with a view to guarding against the joints of the ribs being softened when the machine came down into the water, as it was planned for it to do at the close of its flight, and these submersions had apparently shown that no trouble need be anticipated from the effects of the sustaining surfaces getting wet. It is an instance of the unpredictable delays which present themselves, that when preparations had been begun for the immediate trial of the large machine, already down the river, it was found that every one of the cross ribs had been rendered almost useless by the damp, though under shelter. As it would take months to build new ones, a temporary means of repairing them was used. There were other delays too numerous to mention, but chiefly incident to working over the water, some of the principal of which were due to storms dragging the house boat from its moorings and destroying auxiliary apparatus, such as launches, boats, rafts, etc., to say nothing of the time consumed in bringing workmen to and from the scene of the experiments. The propellers were even found to break under the strain of the actual

engines in the open, though they had not done so in the shop, and this is mentioned as another instance of the numerous causes of trying delay which it was impossible to foresee.

Finally, however, on the 3d of September, everything seemed to be in readiness for the experiments, and the large aerodrome was accordingly placed in position and all orders given and arrangements made for a test that day. After stationing the various tugs, launches, etc., at their predetermined positions so that they might render any assistance necessary to the engineer or the aerodrome, in case it came down in the water at a point distant from the house boat, and after the photographers, with special telephoto cameras, had been stationed on the shore in order that photographs with their trigonometrical data might be obtained, from which speed, distance, etc., might be later determined, and when everyone was anxiously expecting the experiment, a delay occurred from one of the hardly predictable causes just mentioned in connection with the weather. An attempt was made to start the engine so that it might be running at its proper rate when the aerodrome was launched into free air after leaving the track, but the dry batteries used for sparking the engine, together with the entire lot of several dozen which were on hand as a reserve, had become useless from the dampness.

I have merely instanced some of these causes of failure when everything was apparently ready for the expected test, but only one who was on the spot and who had interest in the outcome could appreciate trials of this sort, and the delays of waiting for weather suitable for experiments.

It was found that every storm which came anywhere in the vicinity, immediately selected the river as its route of travel, and although a 10-mile wind on the land would not be an insurmountable obstacle during an experiment, yet the same wind on the river rendered it impossible to maintain the large house boat on an even keel and free from pitching and tossing long enough to make a test.

While speaking of the difficulties imposed by the weather, it should also be understood that to take the aerodrome in parts from under the shelter of the roof and assemble and mount it upon the upper works was a task requiring four or five hours, and that during this time a change in the weather was altogether likely to occur, and did repeatedly occur, sufficient to render the experiment impossible. Experience has shown, then, that the aerodrome should be sheltered by a building, in which it shall be at all times ready for immediate launching. During all the delay resulting from this and other causes—since it was never known on what day the experiment might take place—a great expense for tug boats waiting at a distance of 40 miles from the city, was incurred, and this was a part of the con-

tinuous drain on the pecuniary resources, which proved ultimately more fatal than any mishap to the apparatus itself.

Following the 3d of September, and after procuring new batteries, short preliminary tests inside the boat were made in order to make sure that there would be no difficulty in the running of the engine the next time a fair opportunity arrived for making a test of the machine in free flight. Something of the same troubles which had been met with in the disarrangement of the adjustments of the small engine was experienced in the large one, although they occurred in such a different way that they were not detected until they had caused damage in the tests, and these disarrangements were responsible for broken propellers, twisted shafts, crushed bearings, distorted framework, etc., which were not finally overcome until the 1st of October. After again getting everything in apparent readiness, there then ensued a period of waiting on the weather until the 7th of October (1903), when it became sufficiently quiet for a test, which I was now beginning to fear could not be made before the following season. In this, the first test, the engineer took his seat, the engine started with ease and was working without vibration at its full power of over 50 horse, and the word being given to launch the machine, the car was released and the aerodrome sped along the track. Just as the machine left the track, those who were watching it, among whom were two representatives of the Board of Ordnance,[a] noticed that the machine was jerked violently down at the front (being caught, as it subsequently appeared, by the falling ways),[b] and under the full power of its engine was pulled into the water, carrying with it its engineer. When the aerodrome rose to the surface it was found, that while the front sustaining surfaces had been broken by their impact with the water, yet the rear ones were comparatively uninjured. As soon as a full examination of the launching mechanism had been made, it was found that the front portion of the machine had caught on the launching car, and that the guy post, to which were fastened the guy wires which are the main strength of the front surfaces, had been bent to a fatal extent.

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[a] Major Macomb, of the Board of Ordnance, states in his report to the Board, that "the trial was unsuccessful because the front guy post caught in its support on the launching car and was not released in time to give free flight, as was intended, but, on the contrary, caused the front of the machine to be dragged downward, bending the guy post and making the machine plunge into the water about 50 yards in front of the house boat."

[b] This instantaneous photograph, taken from the boat itself and hitherto unpublished, shows the aerodrome in motion before it had actually cleared the house boat. On the left is seen a portion of a beam, being a part of the falling ways in which the front wing was caught, while the front wing itself is seen twisted, showing that the accident was in progress before the aerodrome was free to fly.

The machine, then, had never been free in the air, but had been pulled down as stated.

The disaster just briefly described had indefinitely postponed the test, but this was not all. As has been said before, the weather had become very cold and the so-called equinoctial storms being near it was decided to remove the house boat at the earliest time possible, but before it could be done, a storm came up and swept away all the launches, boats, rafts, etc., and in doing so completely demolished the greater part of them, so that when the house boat was finally removed to Washington, on the 15th of October, these appurtenances had to be replaced. It is necessary to remember that these long series of delays worked other than mere scientific difficulties, for a more important and more vital one was the exhaustion of the financial means for the work.

Immediately upon getting the boat to Washington the labor of constructing new sustaining surfaces was begun, and they were completed about the close of November. It was proposed to make a second attempt near the city, though in the meantime the ice had formed in the river. However, on the 8th of December, 1903, the atmosphere became very quiet shortly before noon and an immediate attempt was made at Arsenal Point, quite near Washington, though the site was unfavorable. Shortly after arriving at the selected point everything was in readiness for the test. In the meantime the wind had arisen and darkness was fast approaching, but as the funds for continuing the work were exhausted, rendering it impossible to wait until spring for more suitable weather for making a test, it was decided to go on with it if possible. This time there were on hand to witness the test the writer, members of the Board of Ordnance, and a few other guests, to say nothing of the hundreds of spectators who were waiting on the various wharves and shores. It was found impossible to moor the boat without a delay which would mean that no test could be made on account of darkness, so that it was held as well as possible by a tug, and kept with the aerodrome pointing directly into the wind, though the tide, which was running very strong, and the wind, which was blowing 10 miles an hour, were together causing much difficulty. The engine being started and working most satisfactorily, the order was given by the engineer to release the machine, but just as it was leaving the track another disaster, again due to the launching ways, occurred.[a]

[a] Major Macomb again states in his official report to the Board: "The launching car was released at 4.45 p. m. * * * The car was set in motion and the propellers revolved rapidly, the engine working perfectly, but there was something wrong with the launching. The rear guy post seemed to drag, bringing the rudder down on the launching ways, and a crashing, rending sound, followed by the collapse of the rear wings, showed that the machine had been wrecked in the launching; just how it was impossible to see."

This time the rear of the machine, in some way still unexplained, was caught by a portion of the launching car, which caused the rear sustaining surfaces to break, leaving the rear entirely without support, and it came down almost vertically into the water. Darkness had come before the engineer, who had been in extreme danger, could aid in the recovery of the aerodrome, the boat and machine had drifted apart, and one of the tugs, in its zeal to render assistance, had fastened a rope to the frame of the machine in the reverse position from what it should have been attached and had broken the frame entirely in two. While the injury which had thus been caused seemed almost irreparable to one not acquainted with the work, yet it was found upon close examination that only a small amount of labor would be necessary in order to repair the frame, the engine itself being entirely uninjured. Had this accident occurred at an earlier period, when there were funds available for continuing the experiments, it would not have been so serious, for many accidents in shop tests had occurred which, while unknown to the general public, had yet caused greater damage and required more time for repair than in the present case. But the funds for continuing the work were exhausted, and it being found impossible to immediately secure others for continuing it, it was found necessary to discontinue the experiments for the present, though I decided to use, from a private fund, the small amount of money necessary to repair the frame so that it itself, together with its engine, which was entirely uninjured, might be available for further use if it should later prove possible, and that they themselves might be in proper condition to attest to what they really represent as an engineering achievement.

Entirely erroneous impressions have been given by the account of these experiments in the public press, from which they have been judged, even by experts; the impression being that the machine could not sustain itself in flight. It seems proper, then, to emphasize and to reiterate, with a view to what has just been said, that the machine has never had a chance to fly at all, but that the failure occurred on its launching ways; and the question of its ability to fly is consequently, as yet, an untried one.

There have, then, been no failures as far as the actual test of the flying capacity of the machine is concerned, for it has never been free in the air at all. The failure of the financial means for continuing these expensive experiments has left the question of their result where it stood before they were undertaken, except that it has been demonstrated that engines can be built, as they have been, of little over one-half the weight that was assigned as the possible minimum by the best builders of France and Germany; that the frame can be made strong enough to carry these engines, and that, so far as any possible prevision can extend, another flight would be successful if

the launching were successful; for in this, and in this alone, as far as is known, all the trouble has come.

The experiments have also given necessary information about this launching. They have shown that the method which succeeded perfectly on a smaller scale is insufficient on a larger one, and they have indicated that it is desirable that the launching should take place nearer the surface of the water, either from a track upon the shore or from a house boat large enough to enable the apparatus to be launched at any time with the wings extended and perhaps with wings independent of support from guys. But the construction of this new launching apparatus would involve further considerable expenditures that there are no present means to meet; and this, and this alone, is the cause of their apparent failure.

Failure in the aerodrome itself or its engines there has been none; and it is believed that it is at the moment of success, and when the engineering problems have been solved, that a lack of means has prevented a continuance of the work.

RELATION OF WING SURFACE TO WEIGHT.

By R. von Lendenfeld.[a]

Successive investigators, myself among them, have studied the comparative relation between the weight and the dimensions of flying animals, with special reference to the extent of wing surface. Some hundred species of bats, birds, and flying insects have been examined in this way, the results of these researches being given in the following table, in which the animals are arranged according to weight of body.

Animal.	Weight.	Wing surface.	Wing surface to 1 gram weight.
	Grams.	*Sq. cm.*	*Sq. mm.*
Albatross (*Diomedea exulans*)	12,000	8,000	67
Bustard (*Otis tarda*)	9,600	5,937	62
Sea eagle (*Haliætus albicilla*)	5,000	7,937	160
Stork (*Ciconia alba*)	2,265	4,506	199
Flying fox (*Pteropus edulis*)	1,380	1,630	118
Pheasant (*Phasianus colchicus*)	1,000	880	88
Herring gull (*Larus argentatus*)	1,035	2,380	230
Crow (*Corvus cornix*)	595	1,286	216
Partridge (*Perdix cinerea*)	320	336	105
Dove, pigeon (*Columba livia*)	293	608	207
Sparrow hawk (*Falco tinnunculus*)	260	680	261
Laughing gull (*Larus ridibundus*)	197	662	336
Thrush (*Turdus pilaris*)	100	186	186
Swift (*Cypselus apus*)	33.5	144	430
Sparrow (*Passer domesticus*)	28	76	200
Swallow (*Hirundo rustica*)	18	110	611
Titmouse (*Parus major*)	14.5	62	427
Small bat (*Vespertilio pipistrellus*)	3.7	50	1,351
Sphinx moth (*Sphinx ligustri*)	1.92	18.64	971
Flatbellied dragonfly (*Libellula depressa*)	.6	13.3	2,216
Bumblebee (*Bombus pratorum*)	.44	1.03	234
Swallowtailed butterfly (*Papilio podalirius*)	.34	11.2	3,294
Maiden dragonfly (*Calopteryx virgo*)	.2	13.94	6,970
Cabbage butterfly (*Pieris brassicæ*)	.08	9.28	11,600
Honeybee (*Apis mellifica*)	.074	.39	528
House fly (*Musca domestica*)	.01	.18	1,800
Gnat (*Culex pipiens*)	.003	.3	10,000

It is seen from the foregoing table that the relation of the extent of wing surface to the weight of body is not uniform, as might have been expected, but exceedingly variable. For instance, to 1 gram of weight the bustard has 62 mm² of wing surface, while the cabbage but-

[a] Translated from Naturwissenschaftliche Wochenschrift, November 20, 1904.

terfly has 11,600. Careful observation shows, however, that in the main the variation of this ratio depends on the size of the animal, or, stated in general terms, the wings are relatively larger the smaller and lighter the animal to which they belong. It is shown also that the variations from the general rule depend on the fact that the mode of flight is different in different animals. Some flying creatures overcome weight by the rapid movement of their wings; others, especially at the beginning of a stroke, take advantage of the internal atmospheric currents, and use the enormous resistance of the air for their purpose. The first class, to which the sparrow and the honeybee belong, may be designated as flapping flyers, and the last class, of which the albatross and the sea eagle are examples, as sailing flyers. These extreme types of the so-called flapping and sailing flyers are connected by an unbroken chain of flying creatures, not all of which are so exclusively either flappers or sailers as the birds just named.

As might be expected, the flapping flyers have comparatively small wings, which move swiftly by the aid of powerful muscles, while the wings of the sailers are moved by weaker muscles and more slowly. If we take these two classes into consideration separately, as in the following tables, it is clearly shown that the wing surface increases with decreasing weight of body.

Flappers.

Animal.	Weight.	Wing surface to 1 gram weight.
	Grams.	*Mm*²
Bustard	9,600	62
Pheasant	1,000	88
Partridge	320	105
Sparrow	28	200
Bumblebee	.44	234
Honeybee	.074	528
House fly	.01	1,800
Gnat	.003	10,000

Sailers.

Animal.	Weight.	Wing surface to 1 gram weight.
	Grams.	*Mm*²
Albatross	12,000	67
Sea eagle	5,000	160
Stork	2,265	199
Silver gull	1,035	230
Sparrow hawk	260	261
Laughing gull	197	336
Virgin dragon fly	.2	6,970
Lemon butterfly	.183	28,710

Of this fact there can be no doubt, and the question arises why this is so. Müllenhoff and others who have interested themselves in this inquiry have answered it from the morphological point of view. From the entirely correct principle deduced from the position of these investigators, that with increasing size the linear dimensions increase in the first, the magnitude in the second, and the weight in the third ratio, they conclude that the wing surface is not to be compared directly with the weight, but the square root of this surface with the cube root of the weight. In fact, however, the figures thus obtained show no constancy, even when comparing animals of the same mode of flight. Thus the formula $\frac{\sqrt[2]{\text{surface}}}{\sqrt[3]{\text{weight}}}$ gives in the partridge 4.03, in the sparrow 2.86, and in the bumblebee 1.33.

If, however, such a constancy existed, which we see is not the case, the paradox that lies in the relative increase of wing surface with decreasing weight of body would by no means be set aside; but in similarly formed flying creatures it is not so essential that they shall be morphologically alike as that all shall perform the task of overcoming weight equally well, and thus be functionally the same.

In sustaining and propelling the body it thus becomes a question of the power of the wings to press down upon the air, and this power depends not only on their size, but in a very great degree upon the swiftness of their movement against the air and its consequent resistance. Hence, as is evident, the flapping flyers, whose wings move in a comparatively small angle, have greater lifting power the longer their wings and the more strokes they make in a second.

A sparrow has a wing length of about 10 cm. and makes about 12 wing strokes in a second; a bee with a wing length of approximately 6.3 mm. makes, as Marey has shown, about 190 strokes in a second, 6.3 times 190 about equaling 100 times 12. The slow wing movement used by the sailing birds when needed shows the same. The stork has a wing length of 68 cm. and makes $1\frac{3}{4}$ strokes in a second, and the laughing gull with a wing length of 39 cm. makes $3\frac{1}{2}$ strokes in the same time. In these instances also the results are not dissimilar. In general, one may therefore say that the movement of the wings against the air in many birds of the same mode of flight is of equal rapidity, this being true of the flapping flyers as well as the sailers. Although the smaller flyers have relatively larger wings than the greater, one can not for this reason assert that the movement of the wing surface against the air would be slower.

In view of the biological principle that organs are not greater than demanded by their function, we must conclude from the known facts that the smaller animals need relatively larger wings to accomplish what the larger and heavier attain with their relatively smaller ones.

The fact that a wing surface of 67 mm^2 per gram enables the albatross to sail, while the laughing gull requires 336 mm^2 for the same purpose, and that the bustard gets along with 62, while the sparrow needs 200 and the fly 1,800 mm^2, can be explained only on the supposition that the resistance of the air against moving wings is not directly proportional to their size, but that in enlarging the wings the resisting power of the air against them increases in a greater ratio than their superficial dimensions. Knowing that the air requires an appreciable time to yield to the pressure of the moving wing, and that the larger the wing surface the greater the quantity of air displaced and the greater the resistance of this compressed air to the subsequent wing strokes which must act upon it, it is evident that this conclusion is correct.

There can therefore be no doubt that increasing size of body is accompanied by a relative decrease of wing surface, and from this fact we are able to draw interesting conclusions as to the size of the wings a man would need to be able to fly. If we show the relation of the weight to the size of the wing by the means of coordinates, connecting the points thus gained by a curve, and then extend this curve as demanded by the relative weight of the heaviest animal, we secure an approximate illustration of the wing size which such bodies would require. Since the muscular power of a human being would by no means suffice for flapping flight, it could only be a question of sailing flight in this case. I have therefore drawn a curve for sailing flyers on the principle above indicated, from which the following is deduced:

70 kilograms, weight of body, would require 32 mm^2 of wing surface per gram.
80 kilograms, weight of body, would require 31 mm^2 of wing surface per gram.
90 kilograms, weight of body, would require 30 mm^2 of wing surface per gram.
100 kilograms, weight of body, would require 29.5 mm^2 of wing surface per gram.

According to the foregoing, if the combined weight of the body and the mechanical flying apparatus amounts to 90 kilograms, in order to sail like an albatross a man would require 90,000 times 30, or 2,700,000 mm^2 of wing surface; that is to say, two wings furnishing together 2.7 square meters of surface.

RUMFORD SPECTROHELIOGRAPH OF THE YERKES OBSERVATORY.[a]

By George E. Hale and Ferdinand Ellerman.[b]

INTRODUCTION.

The application of the spectroscope in 1868 to the observation of solar prominences in full sunlight opened an extensive field of research and directed the attention of astronomers to the importance of applying the powerful instruments and methods of the physical laboratory to the study of the sun. Since that time the rise and development of stellar spectroscopy have further emphasized the importance of solar investigation. For it can not be too often repeated that the sun is the only star whose phenomena can be studied in detail; in interpreting the spectroscopic phenomena of all the other stars we must therefore return in every instance to the sun. If its infinitely varied and complex activities were well understood, the problems encountered in the study of stellar evolution would be greatly simplified. But although the constant use of the spectroscope, dating back to the discovery of the chemical constitution of the sun in 1859, has furnished an immense amount of valuable information, there appears to be an exceptional opportunity at the present time to secure new and important results, especially through the use of the large spectroscopes and other powerful instruments of the physical laboratory. For solar spectroscopy has by no means kept pace with laboratory spectroscopy; few large grating spectroscopes, such as are found in every physical laboratory, have ever been employed to study a large image of the sun. This being true, it is less remarkable that other laboratory instruments not so generally available are still awaiting application in solar research.

[a] Abstract, by permission, from the Publications of the Yerkes Observatory, Vol. III, Part I, 1904.

[b] Although this paper has been written by myself, for convenience of reference to previous studies and opinions it belongs also to Mr. Ellerman, because of his important share in the work.—G. E. H.

The widespread interest in total solar eclipses and the great expenditure of time and money so freely made in observing them surely tend to emphasize what has been said. For if it is worth while, as it certainly is, to travel thousands of miles and to undergo hardships in order to spend a few flying seconds in making observations, it would seem no less advantageous to continue solar work at home, where entirely new phenomena can be observed daily with a much smaller expenditure of effort. Total eclipses of the sun will always be of great importance, as the corona can not be observed in full sunlight. But the study of many other solar phenomena, which can be observed whenever the sky is clear, is quite as likely to advance our knowledge of the solar constitution.

It was with some such ideas in mind that the work of the Kenwood Observatory was undertaken in 1888. It seemed obvious that even a very slight appreciation of the subject should suffice to render possible some improvements of method. A first step in this direction was attempted by the invention of the spectroheliograph in 1889. The original purpose of this instrument was the photography of the chromosphere and prominences, in order to simplify and render more accurate the daily delineation of their form. It was subsequently found, as will be shown in the present paper, that the instrument had a far wider range of application, and that it could be applied in directions which had not suggested themselves in 1889.

The principle of the spectroheliograph is exceedingly simple. Imagine a direct-vision spectroscope in which the eyepiece ordinarily employed is replaced by a (second) slit. If an image of the sun is formed on the first slit of this spectroscope, the second slit will permit the passage of only a narrow region of the spectrum corresponding in width to this slit. If the slit is now moved until it coincides with the $H\beta$ line, for example, only hydrogen light will pass through the instrument. If, then, a photographic plate is placed behind and almost in contact with the second slit, and the spectroscope is moved at right angles to its optical axis, an image of the sun, in monochromatic hydrogen light, will be built up on the plate from the successive images of the slit. If the exposure is suitable, the chromosphere and prominences will be shown surrounding this image.

Such is the spectroheliograph in its simplest form. It is obviously immaterial whether the motion be given to the spectroscope, on the one hand, or to the solar image and photographic plate, on the other. It is only necessary that the relative motion of the solar image and first slit be such that light from all parts of the solar disk shall pass successively through the slit, while the photographic plate and second slit experience a corresponding relative motion. The second slit serves simply to isolate any desired line in the spectrum;

hence its width must be such as exactly to include this line and to exclude all light from other parts of the spectrum. It is evident that the spectroheliograph may be considered simply as a form of monochromatic exposing shutter, differing from the ordinary focal plane shutter only through the use of a narrower exposing slit and the inclusion of an optical train which limits the light to a single line in the spectrum.

Although this idea suggested itself to me quite independently in 1889, I subsequently learned that the principle was by no means new. Indeed, Janssen had suggested it as early as 1869, while Braun, of Kalocsa, and Lohse, of Potsdam, had designed instruments involving the same principle in 1872 and 1880, respectively. Indeed, Lohse had constructed and experimented with the instrument he designed, but his work was not successful. This may have been due in part to the fact that the hydrogen line which he employed is not nearly so well adapted for prominence photography as are the H and K lines of calcium. This was one of the difficulties experienced in my first (unsuccessful) experiments, which, through the kindness of Professor Pickering, were made at the Harvard College Observatory in the winter of 1889–1890.

In April, 1891, after the Kenwood Observatory had been equipped with a 12-inch equatorial refractor and a powerful solar spectroscope, a photographic study of the ultra-violet spectrum of the chromosphere and prominences was undertaken in the hope of finding lines better adapted than those of hydrogen for the photography of the prominences. The brilliant H and K lines of calcium, previously observed visually in full sunlight by Professor Young and photographically at total eclipses, were found in all cases to be the most conspicuous lines in the spectrum of the chromosphere and prominences. The remarkable brightness of these lines, and more particularly their position at the center of the dark, broad shades, due to the denser calcium vapor in the lower portion of the solar atmosphere, render them peculiarly well adapted for the purposes of prominence photography. Indeed, it was possible with their aid to obtain good photographs of single prominences merely by opening the slit of the spectroscope to such an extent as to include a considerable part of the prominence and giving a very short exposure to the image formed directly upon a photographic plate. But this method was too limited to be of general application. In order to record photographically the entire surface of the sun, with the chromosphere and prominences, it was necessary to employ the principle of the spectroheliograph, involving the use of narrow slits, moved with reference to the solar image and photographic plate. The first successful spectroheliograph was brought into use at the Kenwood Observatory in January, 1892. After this time it was employed regularly on every clear day until May, 1895,

soon after which the instruments of the Kenwood Observatory were removed to the Yerkes Observatory.

My spectroscopic studies of the sun during the spring and summer of 1891 were not confined to the chromosphere and prominences. It was found that the H and K lines, previously recognized as no less characteristic of the prominences than the hydrogen lines themselves, were reversed from dark to bright in regions scattered all over the solar disk. This fact had not escaped the attention of Professor Young, who had long before remarked the presence of these lines in the neighborhood of active sun spots. But the greater delicacy of the photographic processes showed these bright lines to characterize very extensive regions on the sun's surface, not confined to the immediate neighborhood of spots, but scattered throughout the sun-spot zones, and even extending from pole to pole. It was noticed from the outset that these bright regions corresponded closely with the well-known faculæ, and in my earlier work they were called by this name. It has since become clear, however, that a distinctive term should be adopted, and I now propose the name "flocculi" for the regions on the sun's disk which are shown only on photographs made with the spectroheliograph.

The possibility of photographing these bright regions on the sun's disk with the spectroheliograph at once greatly extended the range of that instrument, as it was thus shown to be capable of recording, not only the prominences, which could be observed, though very laboriously, by visual methods, but also extensive and important phenomena invisible to the eye and not shown on photographs taken in the ordinary manner. Spectroheliographs were accordingly adopted for use at other observatories, first by Mr. Evershed in England, and subsequently (in 1893) by M. Deslandres at the Paris Observatory. Both of these spectroscopists introduced modifications and improvements of the instrument, Mr. Evershed constructing a direct-vision spectroheliograph of remarkable simplicity and beauty, and M. Deslandres, with a different type of instrument, obtaining photographs of great excellence.

It had been hoped and expected that the interruption in the daily series of photographs, caused by removal to the Yerkes Observatory in 1896, would be of short duration, but unfortunately this did not prove to be the case. The 12-inch refractor, devoted at Kenwood entirely to solar work, was needed at the Yerkes Observatory for general purposes. It therefore became necessary to remove the spectroheliograph from this telescope, and to modify the mounting in order to adapt it for general observational work. The spectroheliograph was remodeled for use with the 40-inch refractor as a solar spectroscope, and it was expected that a new spectroheliograph, large enough to photograph the 7-inch (17.8 cm.) image at the focus of

this telescope, would soon be ready for use. But the funds required for the construction of the new spectroheliograph were not forthcoming, and when it finally became possible to undertake work on this instrument (through a grant from the Rumford fund, and the gifts of friends of the observatory) progress was slow, owing to the limited funds available. For a 7-inch solar image, collimator and camera lenses of about 10 inches (25.4 cm.) aperture were needed; but the considerable cost of such lenses rendered their purchase impossible, and a pair of 6¼-inch (15.7 cm.) Voigtländer portrait lenses, obtained from second-hand dealers after a year's search, were adopted. With lenses of this aperture it is evident that much light must be lost at the extremities of the slit, and that the resulting image of the sun must therefore be deficient in brightness at the corresponding limbs. Even after the lenses had been secured, the demands of other phases of the observatory's work greatly retarded the construction of the instrument, and it was not until the latter part of 1899 that it was ready for trial.[a] * *

PRELIMINARY ACCOUNT OF RESULTS OBTAINED WITH THE RUMFORD SPECTROHELIOGRAPH.

Prior to 1903 the Rumford spectroheliograph was used for experimental purposes, the numerous photographs obtained during the sun-spot minimum being of service mainly in perfecting the adjustments of the instrument. It had been expected that the spectroheliograph would be transfered from the 40-inch refractor to the 30-inch cœlostat reflector for the purposes of the daily record; but the destruction of the latter instrument by fire in December, 1902, prevented the realization of this plan.[b] The work with the 40-inch refractor was accordingly resumed in February, 1903, and since the latter part of that month photographs of the calcium flocculi have been made on each clear day (Sundays usually excepted). Since early in April this series has been supplemented by a daily series of (low-level) photographs, made with the slit set at some distance from the center of the H or K band, and since May 16 photographs have been made as often as possible with the Hβ line. In addition to this routine work many photographs of special regions have been taken in a study of the calcium vapor at various levels, and some results have also been obtained with the calcium line λ 4,226.9, the iron line λ 4,383.7, and with various other dark lines. It will thus be seen that while the material represented by the photographs obtained with the Rumford

[a] There follows a description of the Rumford spectroheliograph, for which the reader may consult the original publication.

[b] Through the generosity of Miss Helen Snow the cœlostat reflector has been rebuilt and is now in regular use. A spectroheliograph will soon be employed with it.

spectroheliograph is not yet sufficient for extended generalizations, the variety of phenomena recorded is such as to call for some comment here. A more complete discussion of the results must be reserved for a future occasion.

ON THE NATURE OF THE CALCIUM FLOCCULI.

In my first published note on the bright calcium regions recorded for the first time with the Kenwood spectroheliograph I briefly described the results in the following words:

> The reversed regions are of great extent and in appearance closely resemble faculæ. Several explanations may be suggested to account for them. They may be:
>
> 1. Ordinary prominences projected on the disk.
> 2. Prominences in which H and K are bright, while the hydrogen lines are absent.
> 3. Faculæ.
> 4. Phenomena of a new class, similar to faculæ, but showing H and K bright, and not obtained in eye observations or ordinary photographs because of the brilliant background upon which they are projected.[a]

It was subsequently shown that the bright calcium regions in general coincide closely with the faculæ, and it was concluded that they represent the hot calcium vapor in the upper part of the faculæ and in the lower part of the adjoining chromosphere. Fig. 1, plate III, which is reproduced from a photograph of the K line taken at Kenwood Observatory, shows that the bright reversals of the K line frequently occur in regions of the disk where the continuous spectrum is considerably strengthened. These regions are the faculæ proper. The faculæ, though apparently but little brighter than the photosphere, are conspicuously visible near the sun's limb. This is probably due to the fact that they reach a higher level, and thus escape much of the general absorption exercised by a comparatively thin stratum of a smoke-like nature which lies in close contact with the photosphere. The faculæ are, in general, the regions above which the calcium vapor is hottest and most brilliant.

But it appeared later that the calcium vapor is not confined to the faculæ, but extends beyond their boundaries and frequently occurs in regions of the solar disk where they are absent. The generally close coincidence of the calcium clouds with the faculæ, and a natural hesitation to propose a new name before the results obtained with the spectroheliograph had been sufficiently studied, led me to apply this term to the bright calcium regions photographed with the spectroheliograph. From my present point of view I think it would have tended to clearness, as M. Deslandres has pointed out, if some other name had been adopted.

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[a] Astronomy and Astrophysics, Vol. II (1892), p. 159.

M. Deslandres's latest explanation of the calcium regions is undoubtedly more nearly correct than my earlier one, though at the time I did not appreciate this. His solar investigations at the Paris Observatory were confined for some years to the photography of the spectrum of various parts of the sun's disk, but in 1894 he undertook work with the spectroheliograph. The bright reversals of the H and K lines photographed by M. Deslandres on the sun's disk were at first considered by him to represent the prominences; later he ascribed them to bright regions at the base of the prominences, and finally he spoke of them as the brighter regions at the base of the chromosphere projected on the disk. This last designation now appears to me to describe the facts much more accurately than the term "faculæ" (meaning calcium vapor of the faculæ) at first employed by myself. In suggesting the term flocculi (flocculus, dim. of floccus, "a bit of wool") to distinguish the vaporous clouds photographed on the disk from the underlying faculæ, I have distinctly avoided the use of a name which might in any sense be taken as indicating the nature of the phenomena. A glance at plate III will show that the word is more or less descriptive of the photographs, so far as their appearance is concerned.[a]

It is necessary to speak of calcium flocculi, hydrogen flocculi, etc., as the photographs show that the forms of the various vapors in the same part of the disk are not identical. Some of the phenomena comprised under this name are undoubtedly prominences seen in projection, but most of them correspond to much lower levels, near the base of the chromosphere, or within the reversing layer.

MINUTE STRUCTURE OF THE FLOCCULI.

The extensive literature which embodies the long discussion regarding the "willow leaf" and "rice grain" structure of the photosphere has in large part become obsolete since the publication of Langley's important paper "On the minute structure of the solar photosphere," and of Janssen's excellent photographs, now generally accessible in the first volume of the Annals of the Observatory of Meudon. After speaking of the cloud-like character of the photosphere, Langley goes on to describe the more minute details in the following words:[b]

> Under high powers used in favorable moments, the surface of any one of the fleecy patches is resolved into a congeries of small, intensely bright bodies, irregularly distributed, which seem to be suspended in a comparatively dark medium, and whose definiteness of size and outline, although not absolute, is yet striking by contrast with the vagueness of the cloud-forms seen before, and which we now perceive to be due to their aggregation. The "dots" seen before are con-

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[a] The name was suggested by my friend, Dr. L. F. Barker, after seeing the photographs.

[b] American Journal of Science, Vol. VII (February, 1874).

siderable openings caused by the absence of the white nodules at certain points, and the consequent exposure of the gray medium which forms the general background. These openings have been called pores; their variety of size makes any measurements nearly valueless, though we may estimate in a very rough way the diameter of the more conspicuous at from 2″ to 4″. The bright nodules are themselves not uniformly bright (some being notably more brilliant than their fellows and even unequally bright in portions of the same nodule), neither are they uniform in shape. They have just been spoken of as relatively definite in outline, but this outline is commonly found to be irregular on minute study, while it yet affects, as a whole, an elongated or oval contour. Mr. Stone has called them "rice grains," a term only descriptive of their appearance with an aperture of 3 to 4 inches, but which I will use provisionally. It depicts their whiteness, their relative individuality, and their approximate form, but not their irregular outline, nor a certain tendency to foliate structure which is characteristic of them, and which has not been sufficiently remarked upon. This irregularity and diversity of outline have been already observed by Mr. Huggins. Estimates of the main size of these bodies vary very widely. Probably Mr. Huggins has taken a judicious mean in averaging their longer diameter at 1″.5 and their shorter at 1″, while remarking that they are occasionally between 2″ and 3″, and sometimes less than 1″, in length.

* * * In moments of rarest definition I have resolved these "rice grains" into minuter components, sensibly round, which are seen singly as points of light, and whose aggregation produces the "rice-grain" structure. These minutest bodies, which I will call granules, it will appear subsequently, can hardly equal 0.″3 in diameter, and are probably less.

* * * It seems to me that there is no room for doubt that "filaments" and "granules" are names for different aspects of the same thing; that filaments in reality are floating vertically all over the sun, their upper extremities appearing at the surface as granules, and that in spots we only see the general structure of the photosphere, as if in section, owing to the filaments being here inclined.

* * * Speaking without reference to spectroscopic investigations, it seems to me that we have in the behavior of our filaments a presumption as to the existence of ascending currents in the outer penumbra, and of both ascending and descending currents at the umbral edge; ascending ones being the more usual.

An examination of the minute calcium flocculi photographed with the Rumford spectroheliograph will show that they closely resemble the photospheric "grains" described by Langley and illustrated in Janssen's photographs. Plate VI is reproduced from one of our negatives on the scale chosen for the majority of the photographs in Volume I of the Meudon Annals. This photograph was made with the slit set at the center of the H line on a day when the seeing was particularly good. In fig. 3, pl. III, squares 10 seconds of arc on a side are shown. These permit of an accurate determination of the size of the individual elements of the structure. Measurements made on our best negatives show that the minute calcium flocculi range in diameter from less than 1 second to several seconds of arc, thus corresponding closely with the "grains" of the photosphere.

On the working hypothesis at present employed to interpret the results obtained with the Rumford spectroheliograph, it is considered

that these minute flocculi are columns of calcium vapor, rising above the columns of condensed vapors of which the photospheric "grains" are the summits.

On such an assumption it becomes interesting to inquire whether the larger calcium flocculi are made up of similar columns of calcium vapor. As a rule, the seeing is hardly good enough to permit a decision to be reached on this point. But under the best conditions there appears to be distinct evidence of a filamentary structure, the filaments seeming to spread out like the branches of a tree (fig. 2, pl. v). It is evident that much light could be thrown on the question if it were possible to photograph sections of the flocculi at different elevations above the photosphere, since in this way the form and size of distinct columns of calcium vapor, if such were present, could be determined at different levels.

FORM AND EXTENT OF CALCIUM FLOCCULI AT VARIOUS ELEVATIONS ABOVE THE PHOTOSPHERE.

Fortunately, it is possible to accomplish this very result, if the present mode of explaining the photographs may be regarded as sound. We have already had occasion to consider some of the characteristics of the H and K reversals of the chromosphere. In the solar spectrum itself the appearance of the H and K lines clearly indicates that calcium vapor occurs under widely different conditions of intensity at various levels above the photosphere. It is a well-known fact that if a considerable quantity of calcium vapor is introduced into an electric arc, broad bands, bright in the center and fading toward both edges, will appear at the position of the H and K lines (fig. 2, pl. III).[a] The width of the bands may be taken as an approximate measure of the density of the calcium vapor, which decreases toward the outer part of the arc, where the bands are reduced to narrow lines. The narrow dark lines at the center of the bright bands are caused by the absorption of the comparatively cool and rare calcium vapor in the outer part of the arc.

A similar condition of things undoubtedly exists in the sun. In the first place, we have broad diffuse dark bands in the solar spectrum at H and K, produced by comparatively dense calcium vapor close to the photosphere. For convenience of reference these bands will be called H_1 and K_1. As the bright reversals at the base of the chromosphere, when photographed at the sun's limb with a tangential slit, or at a total eclipse, are much narrower than these bands, it may be concluded that the dense calcium vapor in the chromo-

[a] Photographed in the electric arc with the solar spectrograph of the Snow horizontal telescope. The grating temporarily employed gives strong ghosts, which are conspicuous in the photograph.

sphere lies beneath the lowest level that can be observed at the limb. On the basis of Kirchhoff's law, the comparative darkness of these bands in the solar spectrum would be ascribed to the fact that the calcium vapor which they represent is cooler than the photosphere below it. With increasing elevation, in a region of lower pressure, the density of the vapor decreases, and to this decrease of density there corresponds a decrease in the width of the bands. In the lowest portion of the chromosphere that can be observed at the sun's limb the density of the vapor is so far reduced that the broad and diffuse bands are replaced by fairly well-defined lines (H_2, K_2), which maintain their width up to a certain elevation in the chromosphere and then grow narrower, thinning out to much narrower lines (H_3, K_3) in the upper chromosphere and prominences (fig. 2a, pl. II). On the disk H_3 and K_3 appear as fairly narrow dark lines at the center of the broad H_1 and K_1 bands. They occur in practically all parts of the disk, but differ greatly in intensity in different regions. Every bright calcium flocculus on the disk is characterized by the presence of bright H_2 and K_2 lines at the center of H_1 and K_1, with narrow dark H_3 and K_3 lines, due to the absorption of the cooler and rarer vapor in the upper chromosphere superposed upon them. Intensity curves showing these peculiarities of the H and K lines are given by Jewell in the Astrophysical Journal, III (1896), page 100, where the displacements of the lines are also discussed. They are also illustrated in the photographs reproduced in plates II and III.

From a strict application of Kirchhoff's law it would appear that the calcium vapor in the lower chromosphere is actually hotter than the calcium vapor which lies above and below it. It seems improbable that the law can be rigorously applied in this case, and hence it may be necessary to attribute the strong radiation of the intermediate layer to causes other than temperature alone.

In view of the composite character of the calcium lines, it should be possible with the spectroheliograph to photograph sections of the calcium flocculi at levels corresponding to their several elements.[a] If, for example, the second slit were set at the extreme edge of K_1, the resulting photograph should show only that calcium vapor which is dense enough to produce a line of this breadth, i. e., a section across the base of the calcium flocculus, should be obtained. Under no circumstances could the upper and rarer portions of the

[a] Experiments of this kind were not undertaken with the Kenwood spectroheliograph, since the instrument was not well adapted for work with dark lines. Some of the photographs, however, apparently show low-level (K_1) phenomena, and Mr. Evershed informs me that his plates do likewise. M. Deslandres made photographs with K_1 and K_2 in 1894, but I have seen no statements of conclusions derived from a study of the K_1 plates, and do not know whether the method has since been employed at Meudon.

flocculus be shown on such a photograph, since the line they produce is not broad enough to enter the second slit. If the slit were set nearer to the center of the line the photograph should represent a section of the flocculus corresponding to a higher level, where a narrower line is produced. It is evident that while none of the higher and rarer calcium vapor could be shown in this photograph, it might nevertheless include regions lying below it, where the calcium vapor is dense enough to produce a broader line. However, since the calcium vapor is rising from a region of high pressure to one of a much lower pressure, it must expand as it rises, and therefore a section at any level should, in general, be of a larger area than a section of the same flocculus at any lower level. As a consequence of the increasing extent of the vapor with the altitude, and the increase of brightness observed when passing from K_1 to K_2, a photograph corresponding to a given level is not necessarily affected in any considerable degree by the existence of the denser vapor below, except in cases where the high-level vapor does not lie immediately above the low-level vapor. Low-level phenomena, even when very bright, may be wholly concealed by general excess of radiation, or in some cases by absorption, of the calcium vapor at high levels. Moreover, it is of course to be understood that the term "level" is not used here in a strict sense. A section of a large flocculus photographed with K_2 might, for example, correspond to a much greater height above the photosphere than that of the minute flocculi shown on the same photograph. It must never be forgotten, when examining the photographs, that composite effects are very likely to be present.

Such considerations regarding the possibility of photographing sections of the flocculi at different levels are borne out by the photographs, as will be seen by reference to the accompanying illustrations. Plates VII and VIII represent the spot group of 1903, April 29, as photographed with four different settings of the second slit. These were taken within such time limits and in such an order that, as no distinctly eruptive phenomena were present, the principal differences between the photographs are therefore to be attributed to differences in the extent and brightness of the vapor at various levels, and not to changes going on in the sun at the time.

The assumption that these photographs represent sections of the calcium flocculi at different elevations seems to be the simplest and most satisfactory way of explaining the results obtained. Essentially conclusive evidence in favor of this assumption is afforded by the photographs of the recent great sun spot. (Pls. XII to XVIII.)

With the aid of this additional means of research we may return to a consideration of the structure of the flocculi. It has already been remarked that the general surface of the sun appears to be cov-

ered with columns of bright calcium vapor, varying in diameter from less than a second to several seconds of arc, separated by darker spaces, which correspond in appearance to the darker spaces that separate the photospheric "grains." The summits of these columns seem to lie in the second stratum, corresponding to the bright lines H_2 and K_2.

In the larger flocculi the surmise of a structure composed of expanding columns of calcium vapor seems to be borne out by the photographs. Compare, for example, figures 1 and 2 in plate VII. At the lower level (fig. 1) the flocculus is resolved into a series of well-defined elements, of comparatively small area. At the higher level (fig. 2) the area of the entire flocculus is greatly increased, and there seems to be evidence (hardly visible in the cut) that the columns composing it have arched over, so that they are no longer seen end on. Few photographs are sufficiently well defined to bring out such details, and it can not be said with certainty that the effects seen at the higher level are always due to separation and bending of the columns, as well as to expansion of each of the individual columns. In any event, the increase in area at this level is sometimes very great, in many cases sufficient to cover not only the penumbra, but also entire spots. Another illustration of the expansion at increasing altitudes may be seen in the four photographs, corresponding to different levels, which are reproduced in plates VII and VIII. A much finer illustration is afforded by the photographs in plates XI to XVIII of the recent great sun spot.

HYDROGEN FLOCCULI.

The method of photographing the sun with the aid of the dark Fraunhofer lines has already been explained. The spectroheliograph is employed exactly as in the case of the bright calcium lines, but the dispersion is increased sufficiently to insure that the width of the dark lines shall be greater than that of the second slit. Under such circumstances photographs corresponding to the hydrogen lines, or to any other dark lines of sufficient width, may be obtained.

The first photograph made with a dark hydrogen line ($H\beta$) was taken with the Rumford spectroheliograph on May 16, 1903. On developing the plate we were surprised to find a structure differing materially from that obtained with H_2 and K_2. Closer examination and a comparison of the photograph with a K_2 photograph made on the same day showed that the bright calcium flocculi were replaced on the $H\beta$ photograph by dark structures of similar, though by no means identical, form. There could be no doubt about the adjustment of the $H\beta$ line on the second slit, since a prominence was shown on the photograph extending above the sun's limb. At a point near a sun spot a brilliant object appeared. The same bright object was

found on a high-level K_2 photograph, but it did not appear on a K_1 photograph. This was confirmed by other exposures.

The results given by this first photograph have been borne out in subsequent work. It is found that the hydrogen flocculi are in general dark, though they are sometimes bright in disturbed regions, usually in the neighborhood of sun spots.[a]

CONCLUDING REMARKS.

In concluding, we may perhaps be permitted to speak of a few of the numerous investigations which can be undertaken by the student of solar physics. If proper use is to be made of the numerous methods of research which are now available, a large number of investigators will be needed, working, if, possible, on some cooperative plan, at many stations widely separated in longitude. Even the adequate use of the spectroheliograph alone would be beyond the capacity of any single institution, for when suitably designed this instrument will furnish as many photographs of the sun as there are elements present in its atmosphere, and in addition to these many others which represent the peculiarities of certain lines. For example, we have already seen that it will be desirable to ascertain in what degree photographs taken with enhanced lines differ from those taken with other lines of the same element. With a large image of the sun important results might be expected to follow from a study of photographs of sun spots taken with the aid of the widened lines and with bright lines or other lines which are peculiar to the spot. In view of the constant changes which are going on in the sun, a few photographs made in any of these ways will not suffice. What is wanted are series continued through at least one sun-spot period, in order to discover the laws which govern the intensity and the distribution of the various gases and metallic vapors. Furthermore, the great importance of eruptive phenomena, their comparative rarity, and the brief time in which all their phases are exhibited, call for special preparations and methods of work. Spectroheliographs capable of taking several photographs at once through different lines will be essential for any suitable study of eruptive phenomena. If a chain of observatories well distributed in longitude could arrange their work so as to keep the sun almost constantly under observation, many important eruptions which are now lost would be recorded.

But it is by no means sufficient merely to take photographs of the sun with the spectroheliograph. In order to extend greatly the range of the attack, and also to explain the spectroheliograph results,

[a] Many additional interesting details and conclusions regarding both calcium and hydrogen flocculi are given in the original paper and should be consulted by the special reader.

simultaneous observations, both visual and photographic, with other instruments are essential. For example, while a photograph is being taken with the spectroheliograph exposures on the spectrum of the region under investigation, for the purpose of showing the widened lines in sun spots as well as the motions in the line of sight of the calcium vapor in the flocculi, should be provided for. These must be made with an instrument of sufficient dispersion to permit the photographs to be measured with high precision. At the same time large scale photographs of the photosphere and spots, made by direct photographic methods, are needed for comparison with the spectroheliograph results. Many bolometric studies are also required, as well as numerous other investigations which will suggest themselves to the reader. The essential point is that a simultaneous attack should be made on solar phenomena with a series of powerful instruments, each designed to answer definite questions, and thus to furnish some of the material that will be required for solving solar problems.

But such an attack, comprehensive as it might be made, would be greatly hampered if the atmospheric conditions were not favorable. The difference between the effects of good and bad seeing may be seen by comparing the blurred photograph reproduced in fig. 1, plate VII, which was the best that could be obtained at the time, with the (larger scale) photograph reproduced in plate VI, which was made with precisely the same instruments and adjustments at a time when the conditions were unusually good. If such conditions as these latter could be had day after day for long periods of time, with occasional periods of even finer definition, many questions now out of reach could be solved.

A report on the instrumental and atmospheric conditions needed in future work on the sun may be found in the forthcoming Yearbook (No. 2) of the Carnegie Institution.

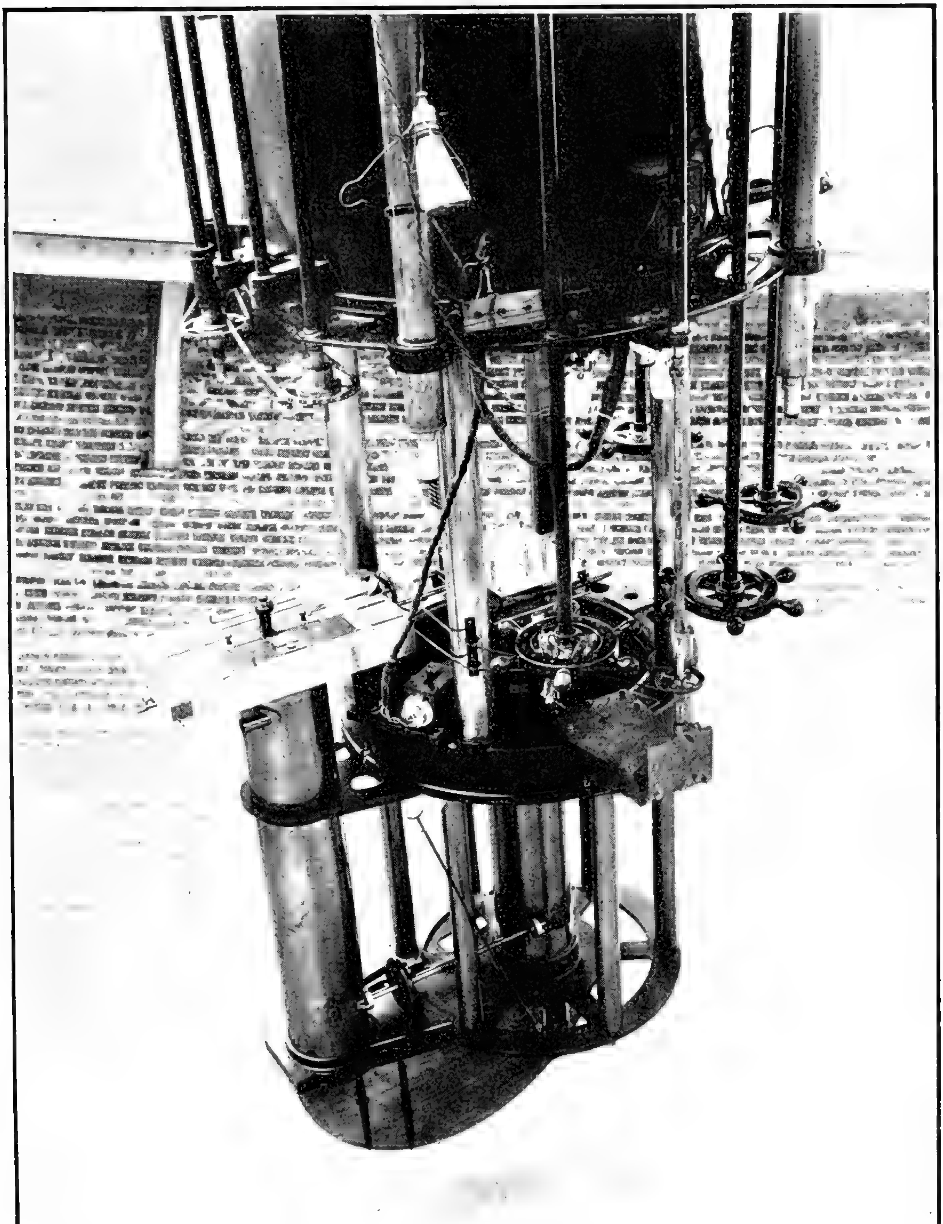
OCTOBER, 1903.

DESCRIPTION OF THE PLATES.

The accompanying illustrations are selected from the quarto plates published in the original work and in some cases are reduced in size.

PLATE I.

The Rumford spectroheliograph, attached to the forty-inch Yerkes refractor. The shaft which is driven by the declination motor may be seen at the right. It carries a grooved pulley near its lower end connected with a similar pulley at the end of the camera box by means of a round leather belt. On the same shaft with this second pulley is a spur gear, which engages with the two gears on the projecting ends of the screws that pass through the camera box. The keys used to operate the split nuts that clamp the plate carriage to the screws, the windows for observing the spectrum at the middle and at the ends of the second slit, and the screw-drivers employed to push forward the plate holder after the slide is withdrawn, are on the top of the camera box. At the left end of the box may be seen the door through which the plate holder is inserted, and the narrow sliding door in its outer face through which the slide is withdrawn, as well as the micrometer heads of the screws for controlling the width of the second slit and for moving it as a whole. The first slit, at the end of the collimator, is almost hidden from view by the metallic screen required to shield its mounting from the great heat of the solar image. Light reaches the first slit through a long narrow opening in this screen. Mounted on four posts above the screen, at such a height as to lie in the visual focal plane when the first slit is at the focus for the K line, is a narrow metallic plate, on which a line is drawn in the direction of dispersion. During an exposure, the limb of the Sun is made to follow this line. At the end of the electric cable may be seen the switches used for operating the declination motor, and (just below) the rod with which the mirror in the prism box is rotated.



THE RUMFORD SPECTROHELIOGRAPH ATTACHED TO THE 40-INCH YERKES REFRACTOR.

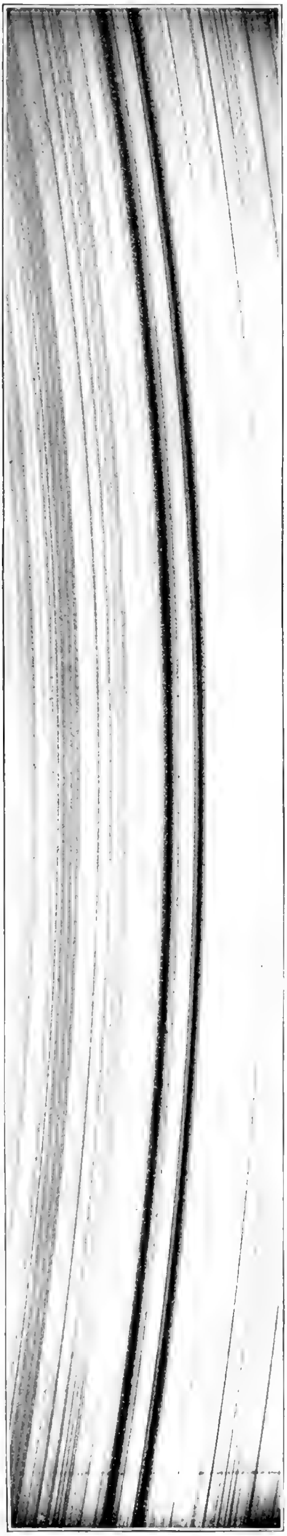


FIG. 1.—CURVATURE OF LINES IN THE SPECTROHELIOGRAPH.

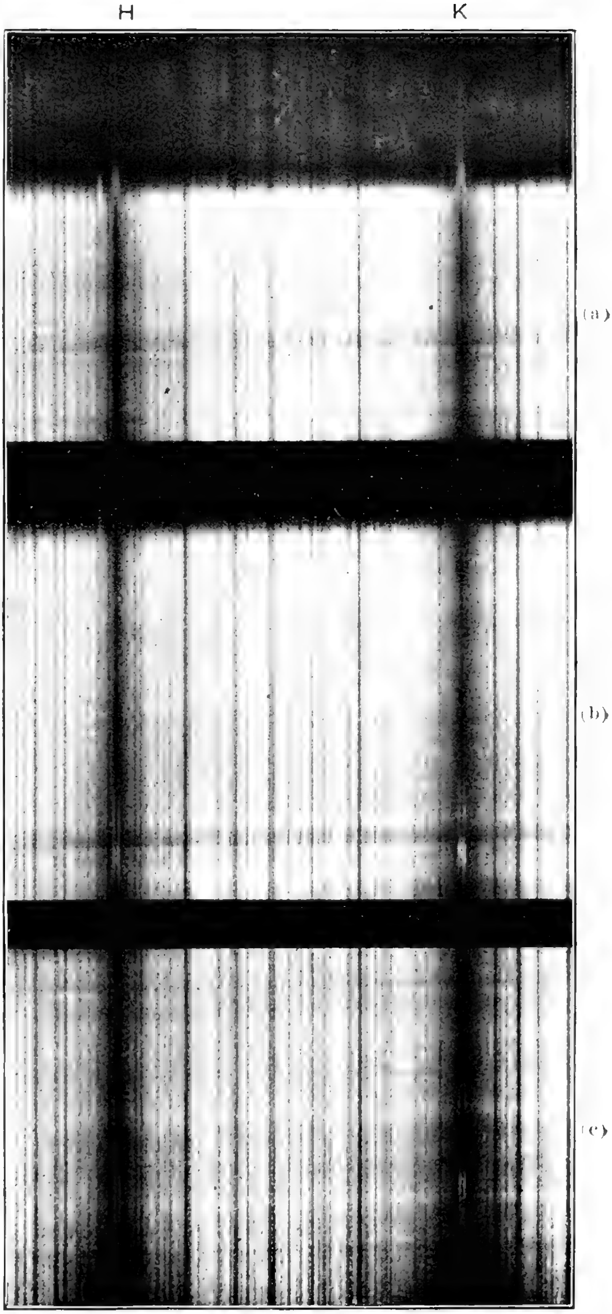


FIG. 2.—H AND K LINES ON THE DISK, IN THE CHROMOSPHERE, AND IN A PROMINENCE (a).

PLATE II.

Fig. 1.—Full-sized reproduction of a photograph of the H and K lines in the solar spectrum, made with the curved first slit. The two curved slits regularly employed with the spectroheliograph to eliminate distortion of the solar image have a radius of 522 mm., equal to that of the curved lines here shown.

Fig. 2.—H and K lines on the solar disk and in the chromosphere (radial slit).

Fig. 2a.—Shows H_3 and K_3 (very faintly) in a prominence.

PLATE III.

FIG. 1.—The K line on the solar disk and in the chromosphere at the limb (radial slit). The bright reversals (K_2) are due to the flocculi. Where faculæ are present the continuous spectrum is more or less strengthened.

FIG. 2.—Reversals of the H and K lines in the electric arc, showing the decrease in width from the inner (dense) to the outer (rare) calcium vapor.

FIG. 3.—Minute calcium flocculi, resembling the granulation of the photosphere. The squares are 10″ of arc on a side.

FIG. 1.—K LINE ON THE DISK AND AT THE LIMB.

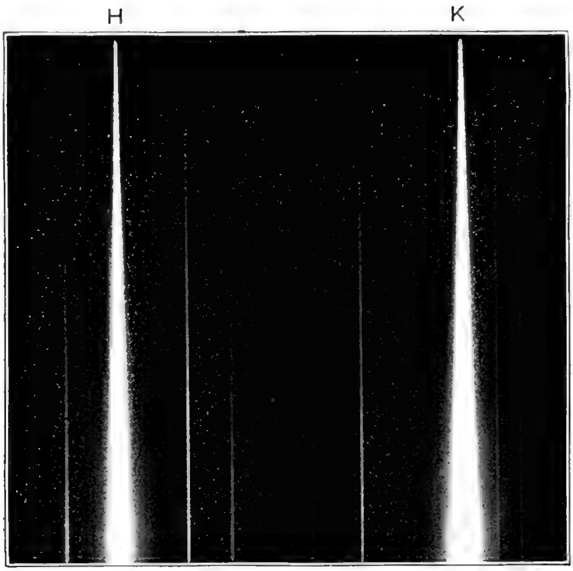


FIG. 2.—H AND K LINES IN ELECTRIC ARC, SHOWING REVERSALS.

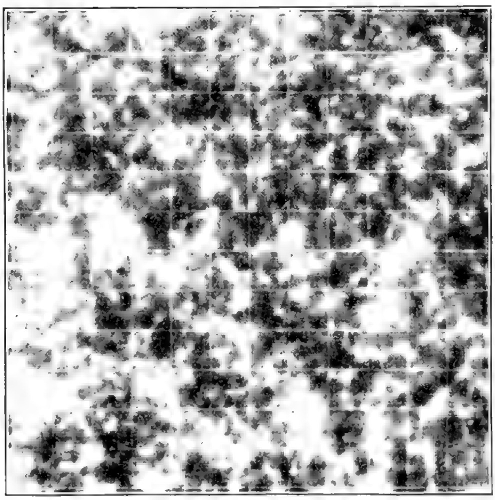
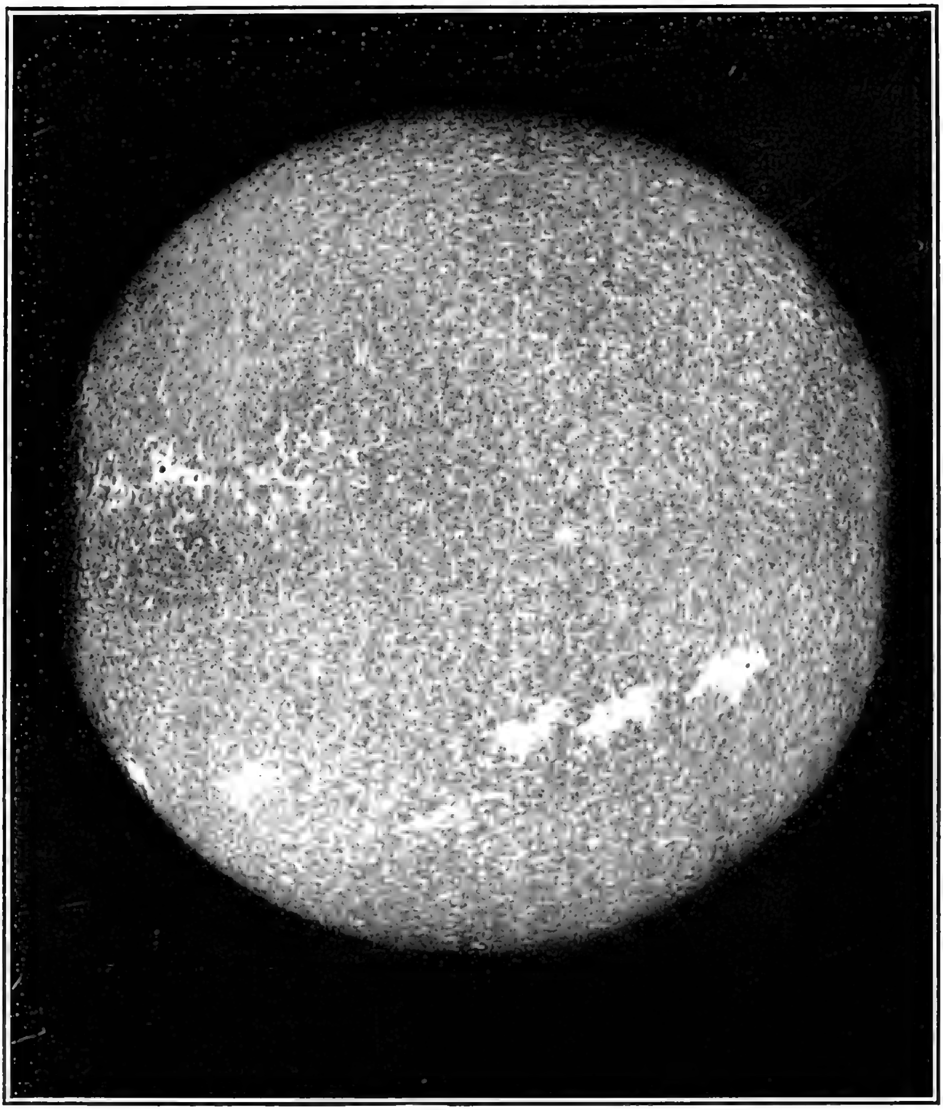


FIG. 3.—MINUTE CALCIUM FLOCCULI (H_2).

The squares are 10 inches on a side.

N

E  W

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THE SUN, SHOWING CALCIUM FLOCCULI (H₂ LEVEL), AUGUST 12, 1903, $8^h\ 52^m$. C. S. T.

PLATE IV.

Entire disk of the Sun, as photographed August 12, 1903, $8^h\ 52^m$ C. S. T. with the H_2 line. Same size as original negative. The squares of the half-tone screen are too coarse to permit the smallest details to be shown.

PLATE V.

FIG. 1.—Low level (H_1) section of calcium flocculi, showing how these flocculi appear to be made up of vertical columns of calcium vapor.

FIG. 2.—High level (H_2) section of the same flocculi, showing (faintly) how the vapor columns seem to be bent over at the summit, as well as expanded.

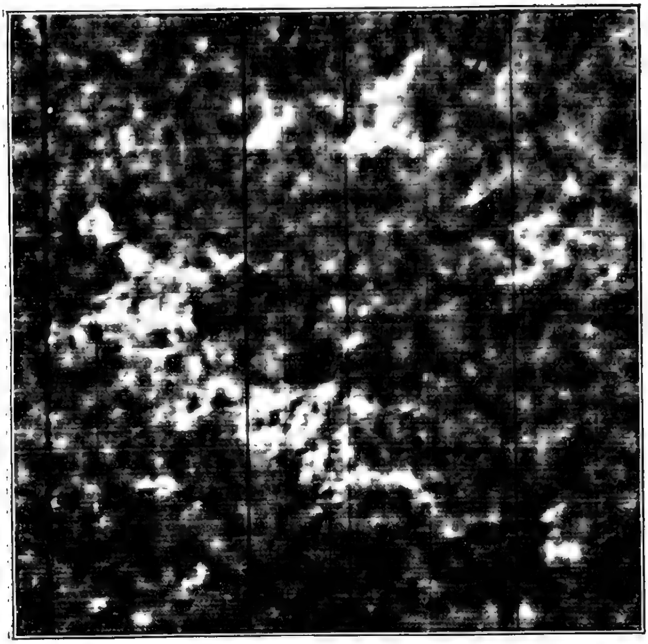


FIG. 1. 3h 40m. Low H_1 level. Slit at λ3962.

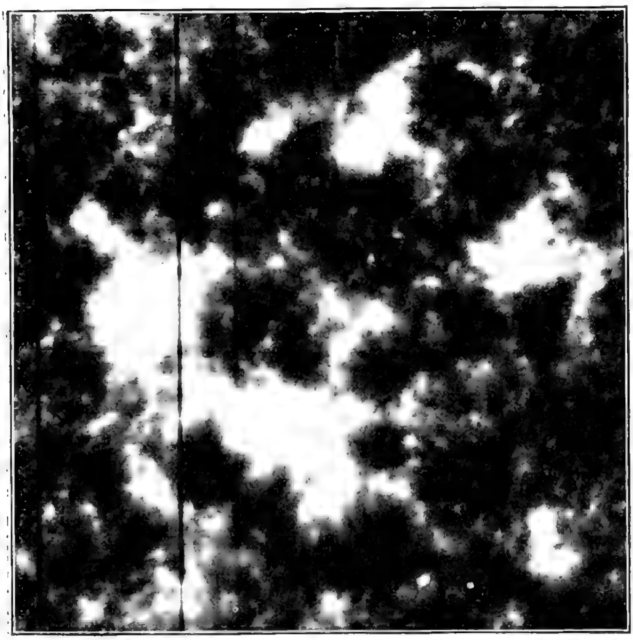
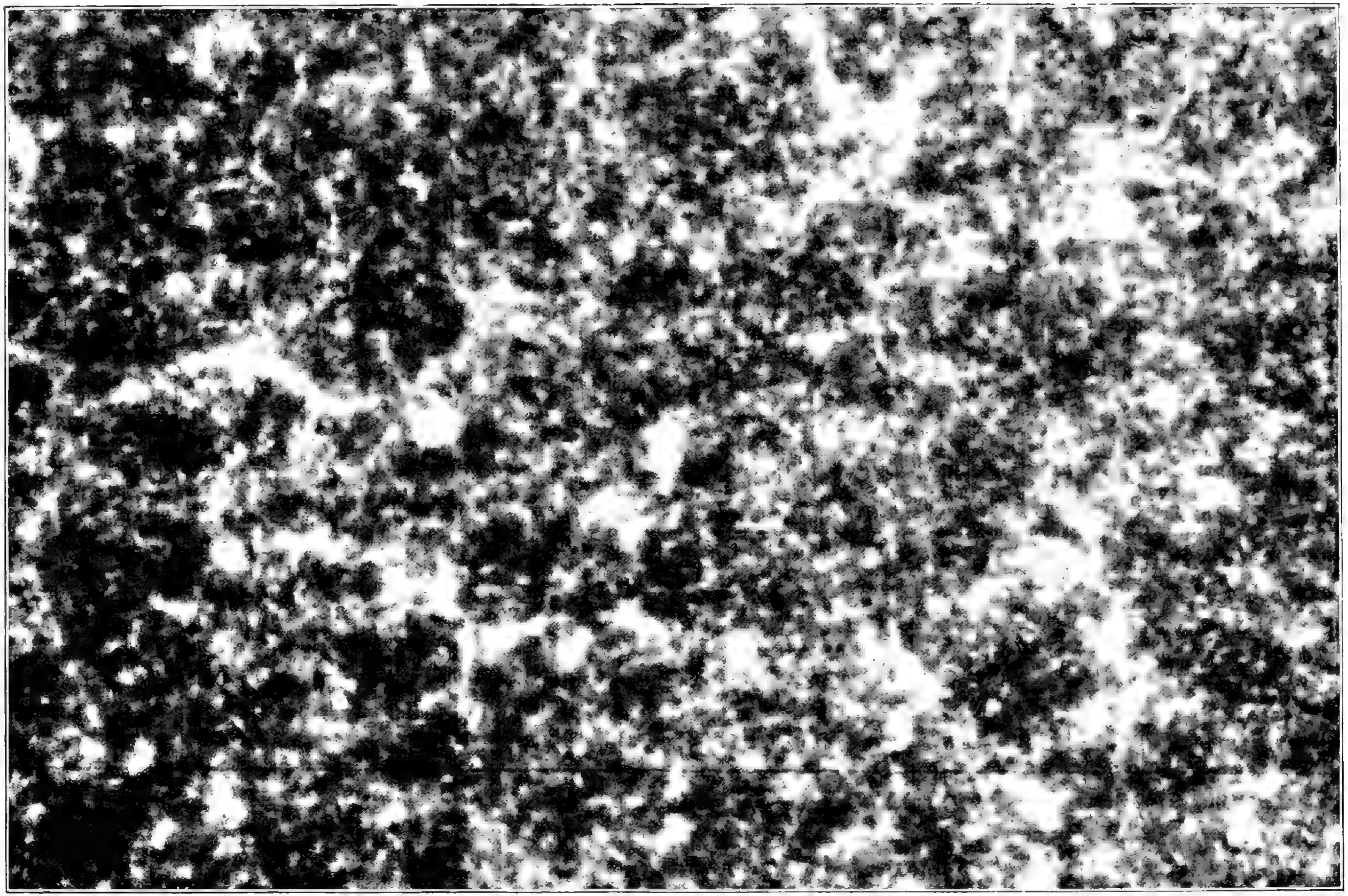


FIG. 2. 3h 31m. H_2 level. Slit at λ3968.6. Same region as fig. 1.

MINUTE STRUCTURE OF THE CALCIUM FLOCCULI, SEPTEMBER 22, 1903.

Scale: Sun's diameter=0.890 meter.



MINUTE STRUCTURE OF THE CALCIUM FLOCCULI, SEPTEMBER 22, 1903.

Scale: Sun's diameter 0.890 meter. $3^h 31^m$. General appearance of sun's disk at H_2 level.

PLATE VI.

Minute calcium flocculi, H_2 level, showing their normal appearance under excellent conditions of seeing.

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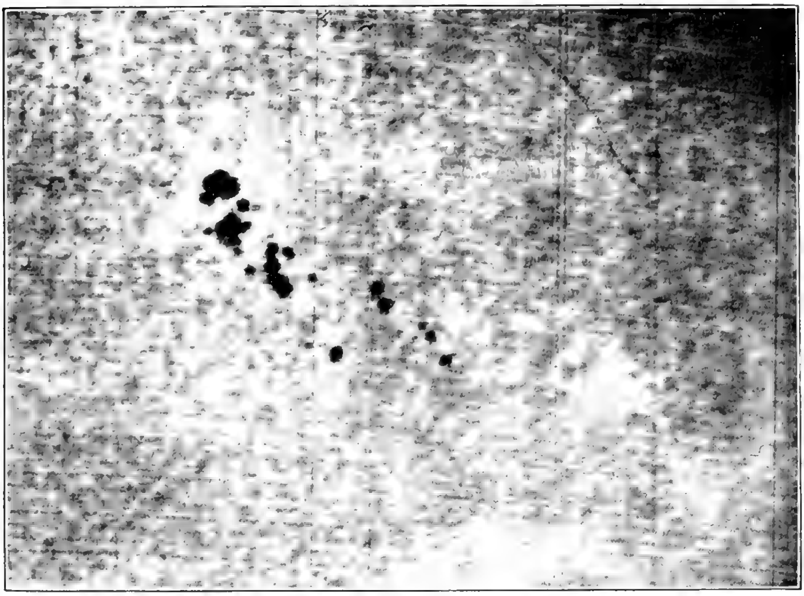
PLATE VII.

FIG. 1.—For this photograph the second slit was set on the continuous spectrum at 3924. Consequently no flocculi are shown, though the faculae are faintly visible. The forms of the latter should be compared with those of the flocculi in the other figures.

FIG. 2.—Low K_1 level. Slit set at 3929. This shows the dense calcium vapor not far above the photosphere. Compare with fig. 1 and note that even at this low level the calcium vapor overhangs and sometimes completely covers small spots.

N



E Fig. 1. $11^h\ 32^m$. Faculæ. Slit on continuous spectrum at λ3924. W

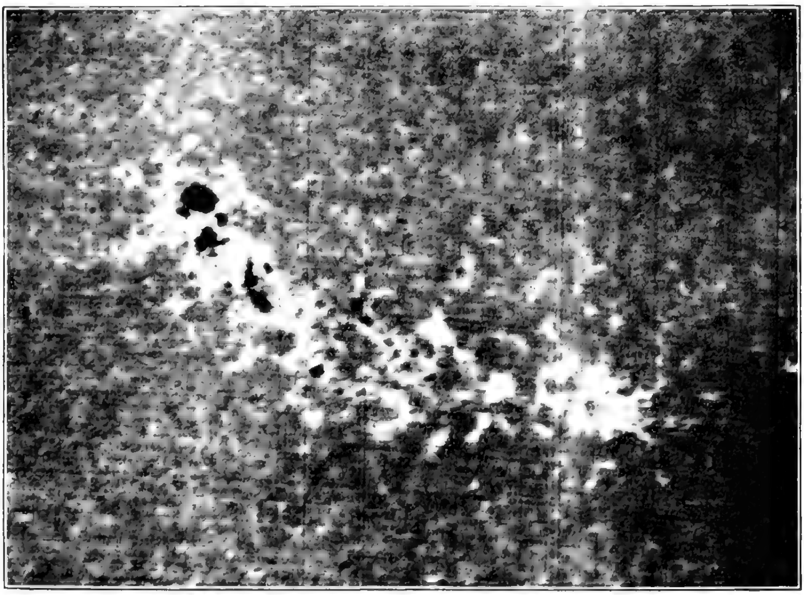


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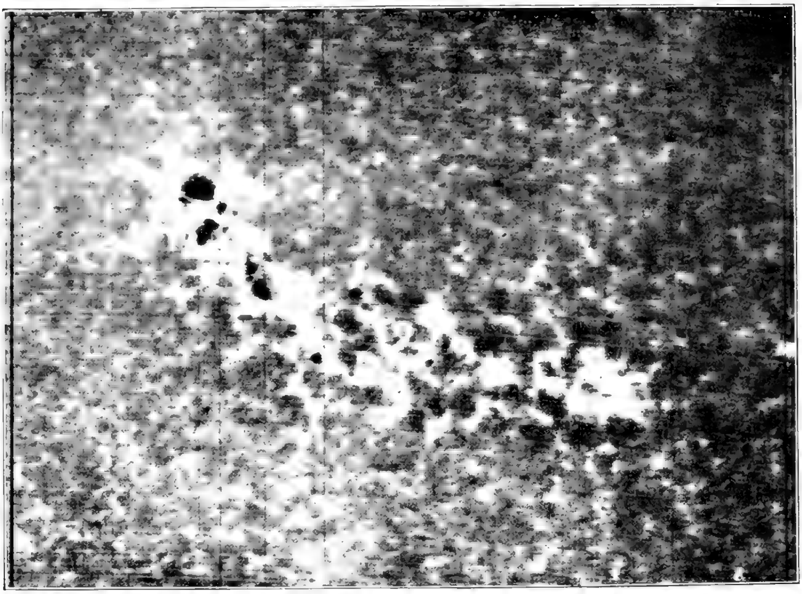
Fig. 2. $11^h\ 22^m$. Calcium flocculi, low K_1 level. Slit at λ3929.

FACULÆ AND SECTION OF CALCIUM FLOCCULI, APRIL 29, 1903.

Scale: Sun's diameter = 0.280 meter.

N



E FIG. 1. $10^{h}\ 28^{m}$. Calcium flocculi, higher K_1 level. Slit at $\lambda 3932$. W

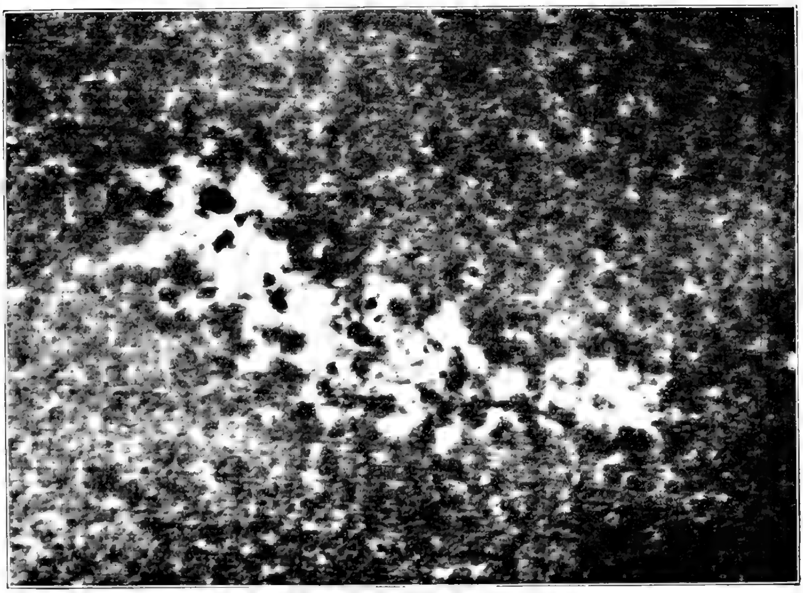


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FIG. 2. $11^{h}\ 11^{m}$. Calcium flocculi, K_2 level. Slit at $\lambda 3933.8$.

SECTIONS OF CALCIUM FLOCCULI AT DIFFERENT LEVELS, APRIL 29, 1903.

Scale: Sun's diameter=0.280 meter.

PLATE VIII.

FIG. 1.—Higher K_1 level. Slit at 3932. Though taken before the photographs reproduced in Plate VII, this picture further emphasizes the differences noted at lower levels. The fact that the changes are progressive largely eliminated the time element, which might otherwise be suspected of causing the observed differences. As a matter of fact, these flocculi are quiescent and slowly changing, differing very decidedly from eruptive phenomena.

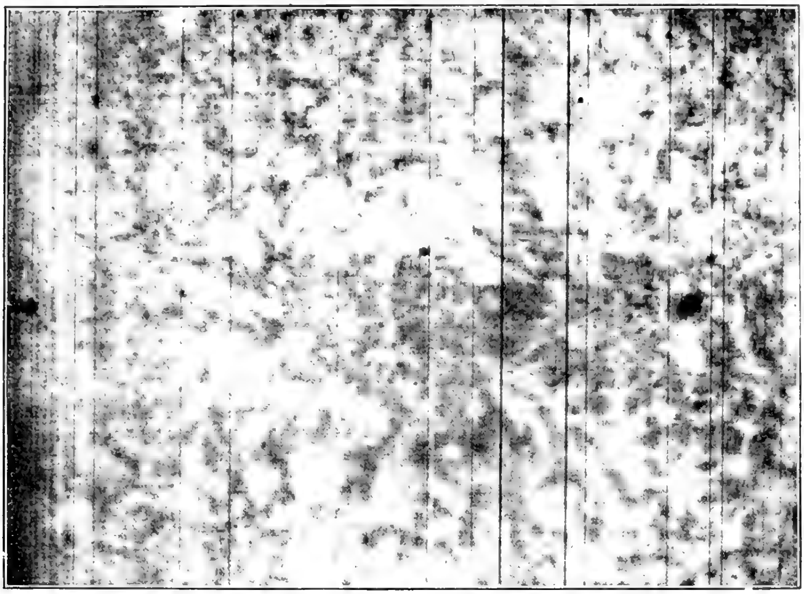
FIG. 2.—K_2 level. Slit at 3933.8. Here the calcium vapor is very brilliant and covers a larger area. The photograph contains distinct evidence of dark absorbing masses at higher levels. Perhaps the best instance of this is the dark tongue which runs somewhat north of west from the small spot south preceding the largest one of the group. This tongue seems to form a part of an extensive dark area, which completely surrounds the bright flocculi of the group.

PLATE IX.

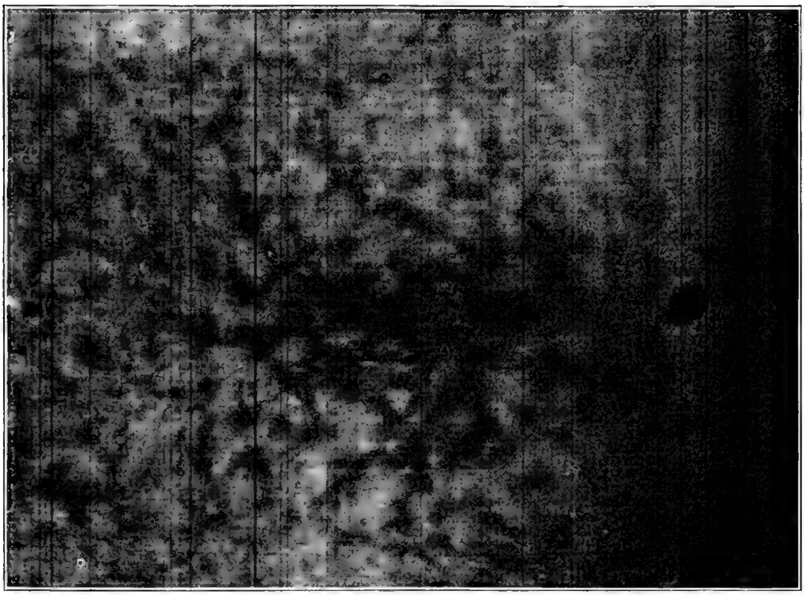
FIG. 1.—As remarked in the text, the contrast is too great in this photograph, and the appearance of the brighter regions is deceptive. In reality the dark regions in general represent the hydrogen flocculi, though there may be a few places near the spot where bright flocculi are present.

FIG. 2.—This cut represents more nearly the appearance of the dark hydrogen flocculi on the negatives. As the slit did not coincide with the *H* line throughout its length, the flocculi are not shown to the west of the spot. A small bright flocculus may be seen at the extreme edge of the figure on the left adjoining the small spot.

N



E FIG. 1. 9h 39m. Hydrogen flocculi. Slit at center of $H\beta$. W



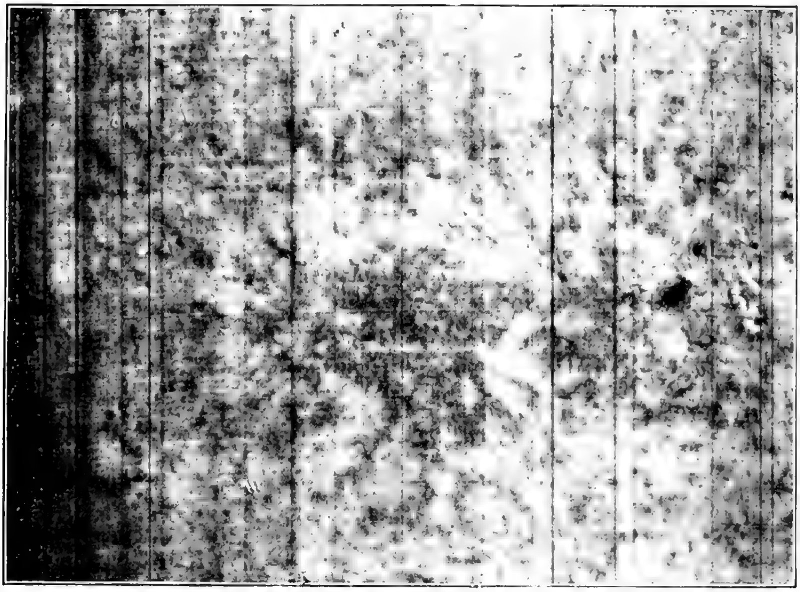
S

FIG. 2. 2h 50m. Hydrogen flocculi. Slit at center of $H\beta$.

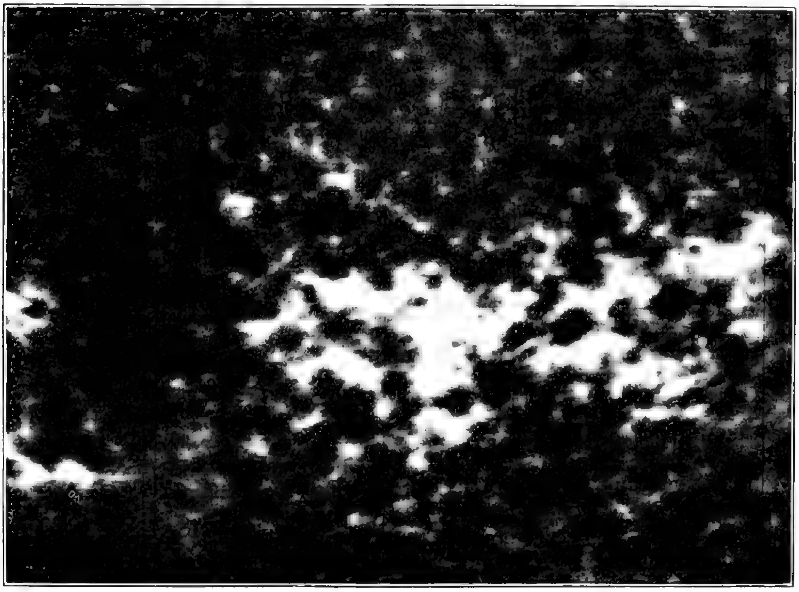
HYDROGEN FLOCCULI, JULY 7, 1903.

Scale: Sun's diameter=0.290 meter.

N



E Fig. 1. 11h 0m. Hydrogen flocculi. Slit at center of $H\gamma$. Bright eruptive flocculi west of spot. W



S

Fig. 2. 3h 57m. Calcium flocculi, K_2 level. Slit at λ3933.8.

HYDROGEN AND CALCIUM FLOCCULI, JULY 7, 1903.

Scale: Sun's diameter=0.290 meter.

PLATE X.

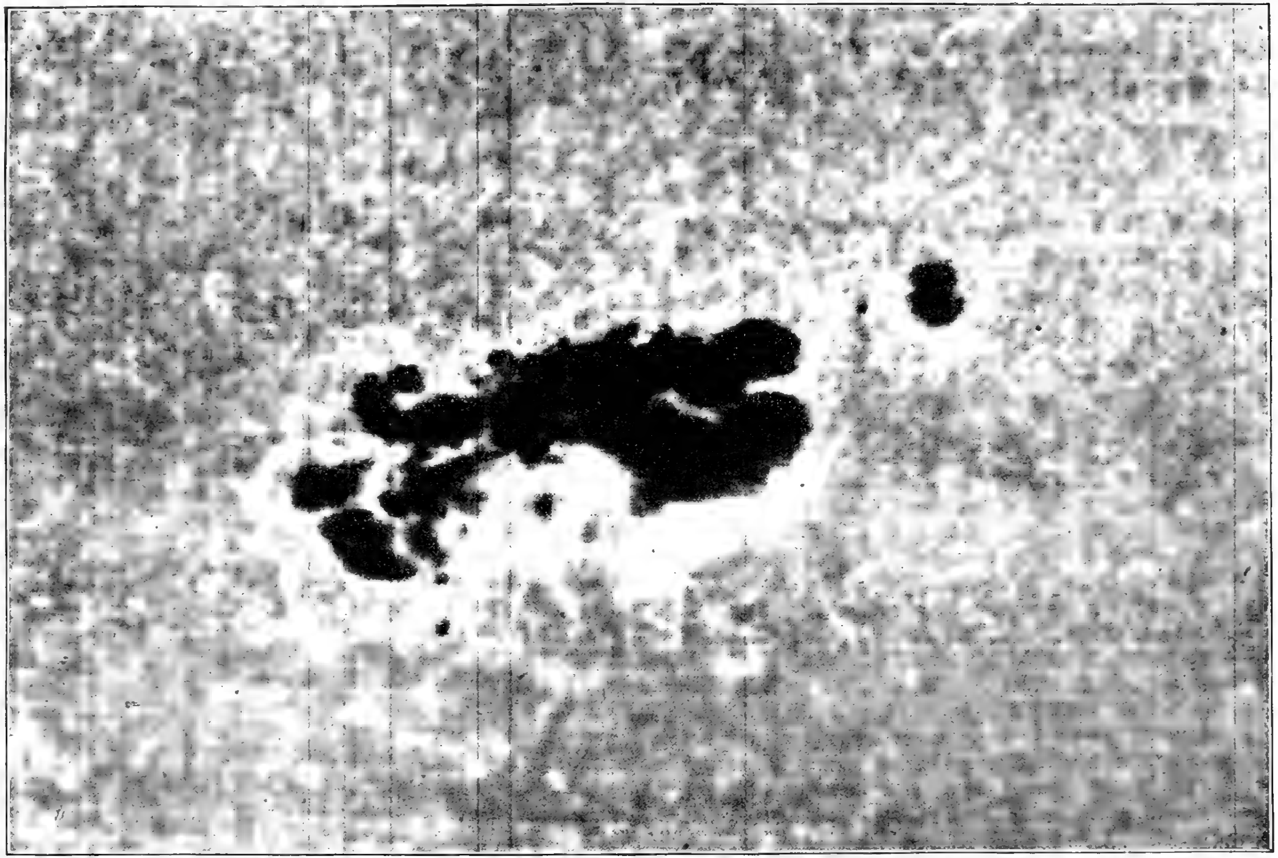
Fig. 1.—The contrast in this photograph is more nearly what it should be, though the background is in general too bright. Some well-defined examples of bright hydrogen flocculi may be seen to the west of the spot, where small spots were developing at the time.

Fig. 2.—The contrast here is rather too great, and for this reason the background appears too dark. The general character of the bright calcium flocculi is nevertheless fairly well shown. The bright tongue extending into the small spot on the left is eruptive in character, and corresponds with the bright hydrogen flocculus referred to in the description of fig. 1.

PLATE XI.

Low-level photograph, showing the dense calcium vapor lying just above the photosphere. In this photograph very little of the penumbra is covered by the calcium vapor, but evidences may be seen, especially in the southern part of the penumbra of the largest spot, of the columns of vapor which are greatly developed at the higher levels.

N

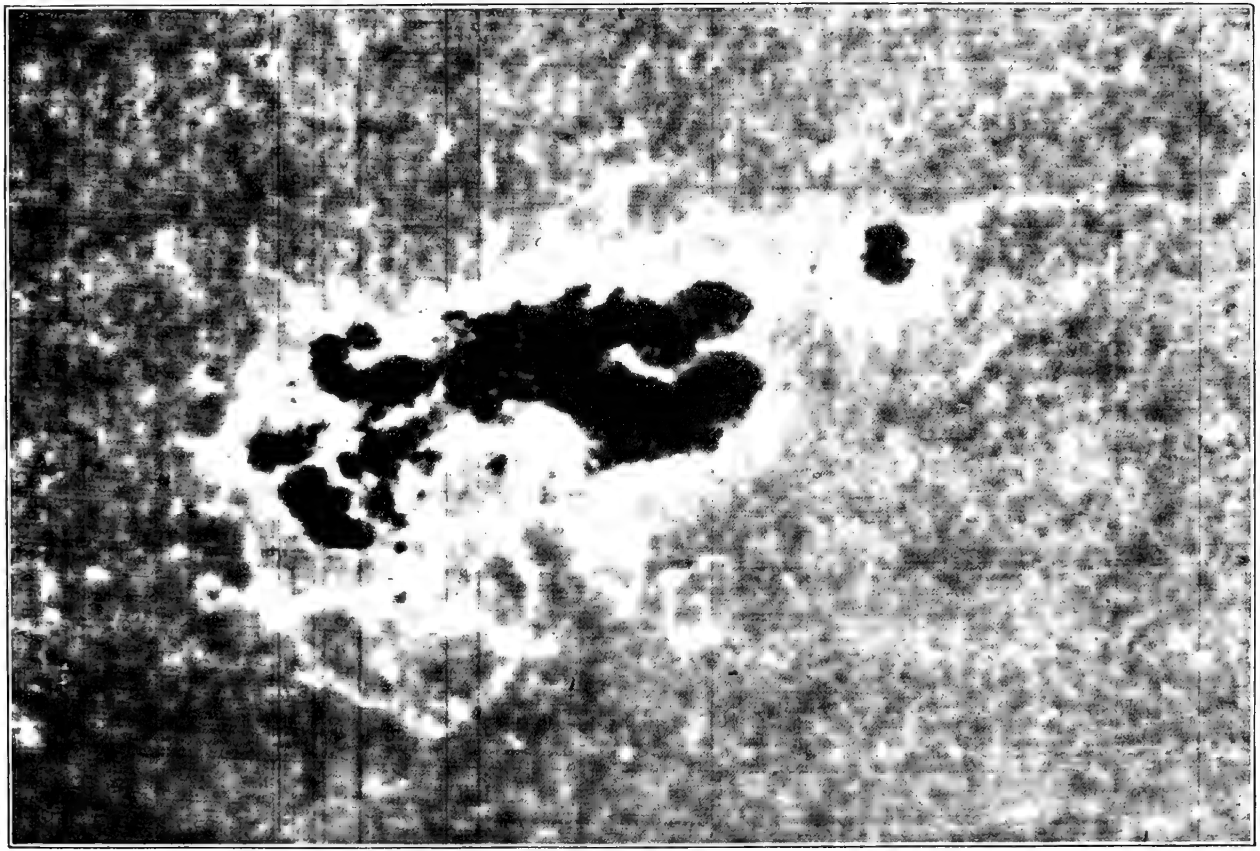
E  W

S

THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, low H_1 level. Slit at λ3962. October 9, 3^h 42^m. Scale: Sun's diameter = 0.550 meter.

N

E  W

S

THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, middle H_1 level. Slit at $\lambda 3966$. October 9, 3^h 43^m. Scale: Sun's diameter=0.550 meter.

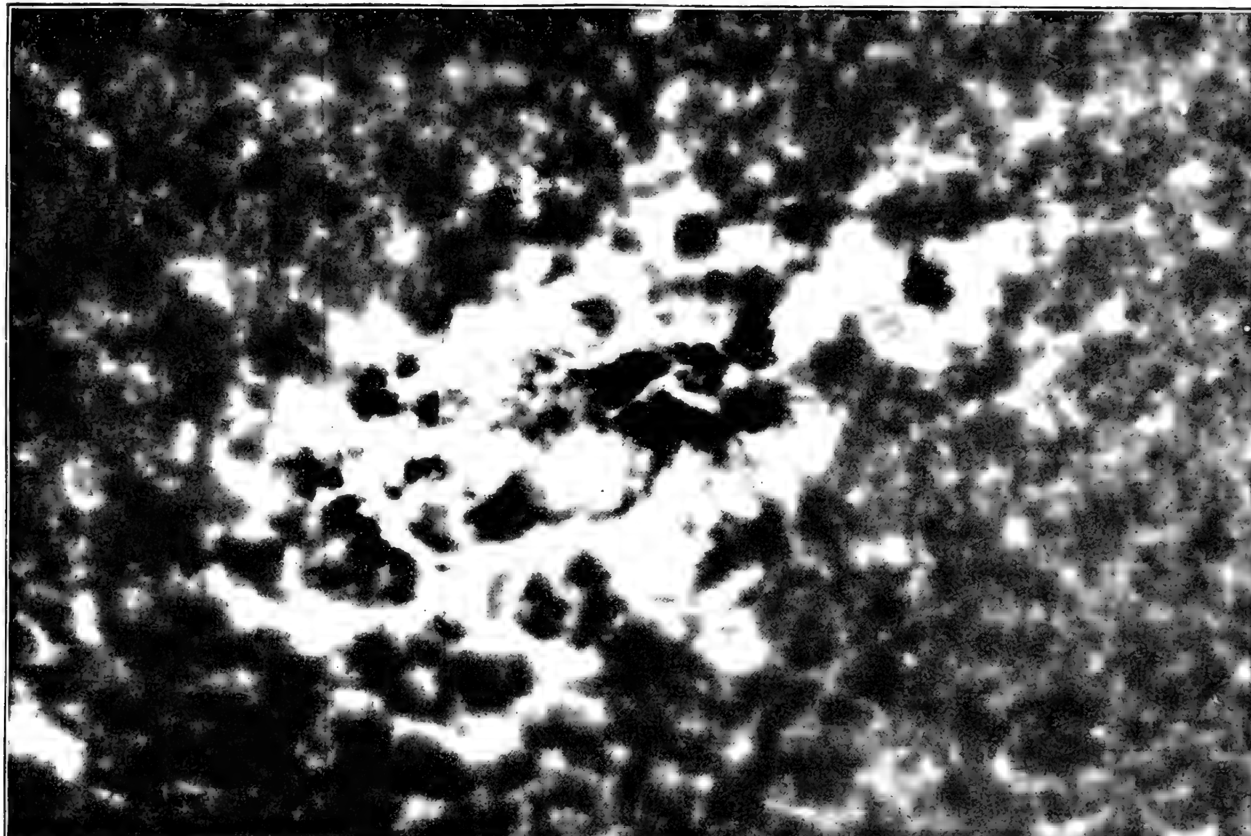
PLATE XII.

In this photograph the calcium vapor is much better shown than in Plate XI, and the beginnings of eruptive phenomena have become more distinctly evident.

It is to be understood that although the changes going on in the eruptive phenomena of the spot group prevent a perfect comparison of all the details of the successive photographs in this and the subsequent series, the large masses of flocculi change so slowly in form that they may be compared without danger of serious error. In general, the differences between the successive pictures are therefore due to differences in the extent and brightness of the vapor at different levels rather than to changes in form which have taken place between exposures. In order to render possible a satisfactory comparison of the high and low level flocculi surrounding this spot, the matched pair of photographs, reproduced in Plates XV, XVI, is given for examination with the stereoscope.

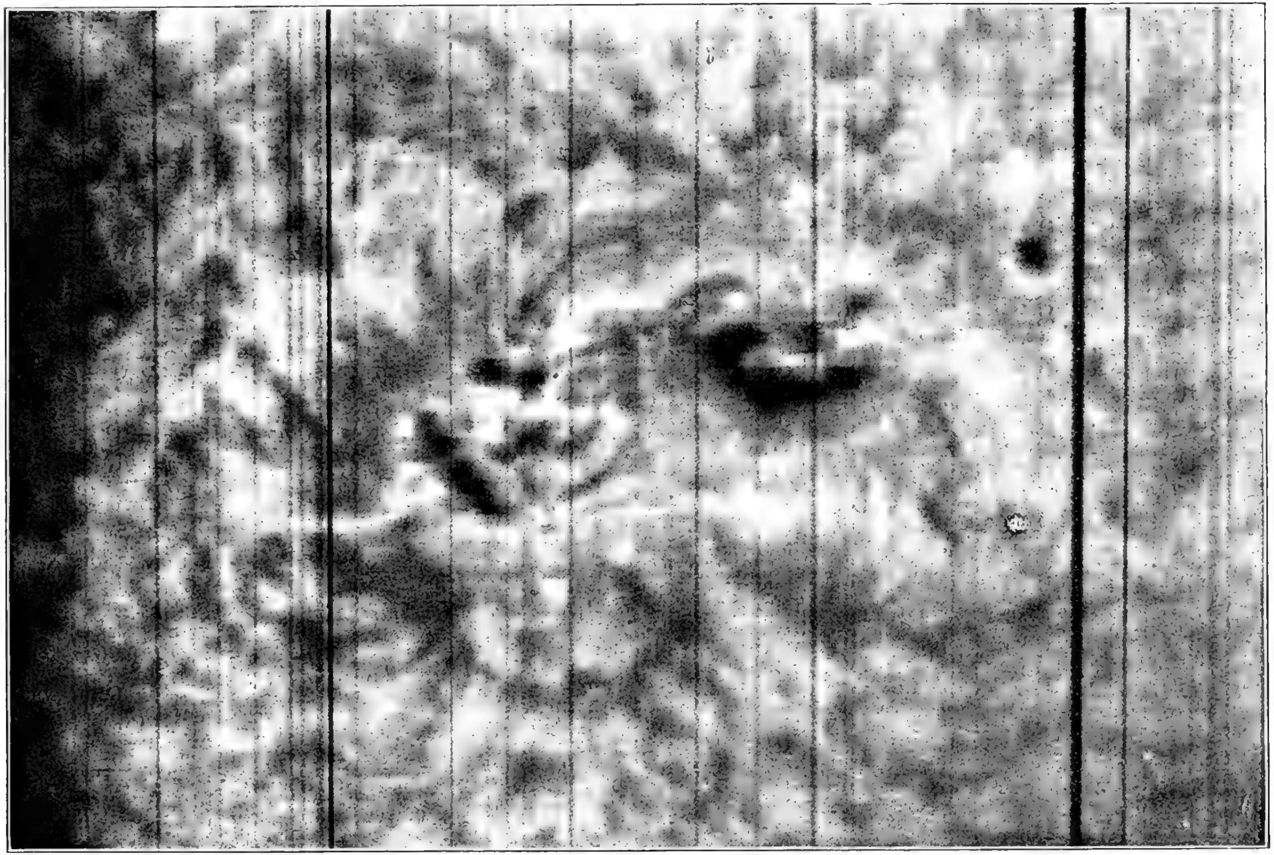
PLATE XIII.

This photograph, which represents the high-level calcium vapor, should be compared with figs. 1 and 2, Plate X. It will be seen that at this level the penumbra is almost completely covered, while many of the smaller spots are blotted out. There are also distinct evidences of dark flocculi, due to absorbing vapors at still higher levels. The illustration necessarily fails to indicate the brilliancy of the brightest eruptive phenomena, which on the original negatives are easily distinguished from the ordinary flocculi.



THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, H_2 level. Slit at λ3968.6. October 9, 3^h 30^m. Scale: Sun's diameter 0.550 meter.



THE GREAT SUN SPOT OF OCTOBER, 1903.

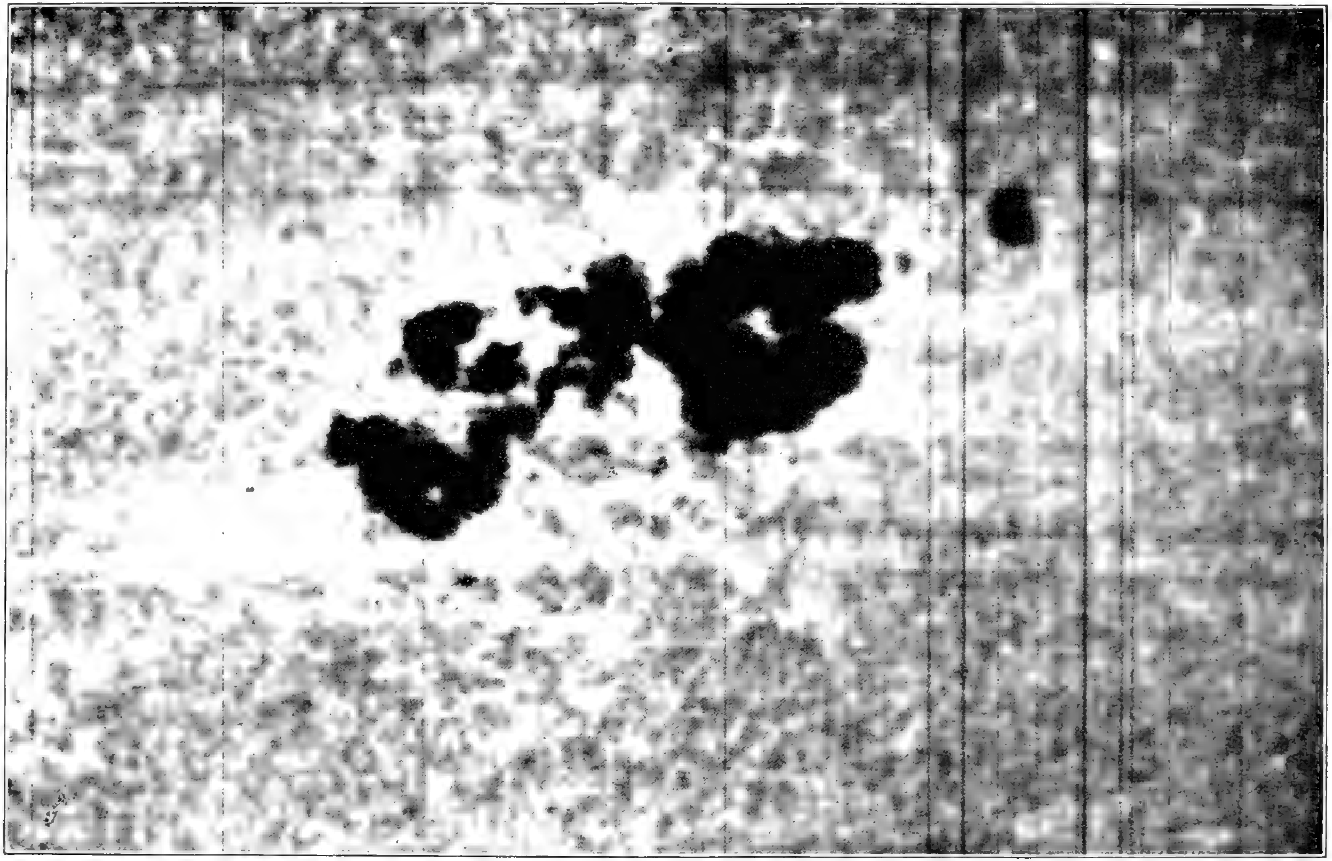
Hydrogen flocculi. Slit set on $H\beta$. October 9, $1^h\ 04^m$. Scale: Sun's diameter, 0.550 meter.

PLATE XIV.

This photograph, which shows the hydrogen flocculi surrounding the spot group, should be compared with fig. 1, Plate X. The brighter regions are in most cases eruptive. In general, the hydrogen flocculi in the less disturbed regions are dark, though they may perhaps be bright or neutral where they overhang the penumbra, and cover some of the smaller spots of the group.

PLATE XV.

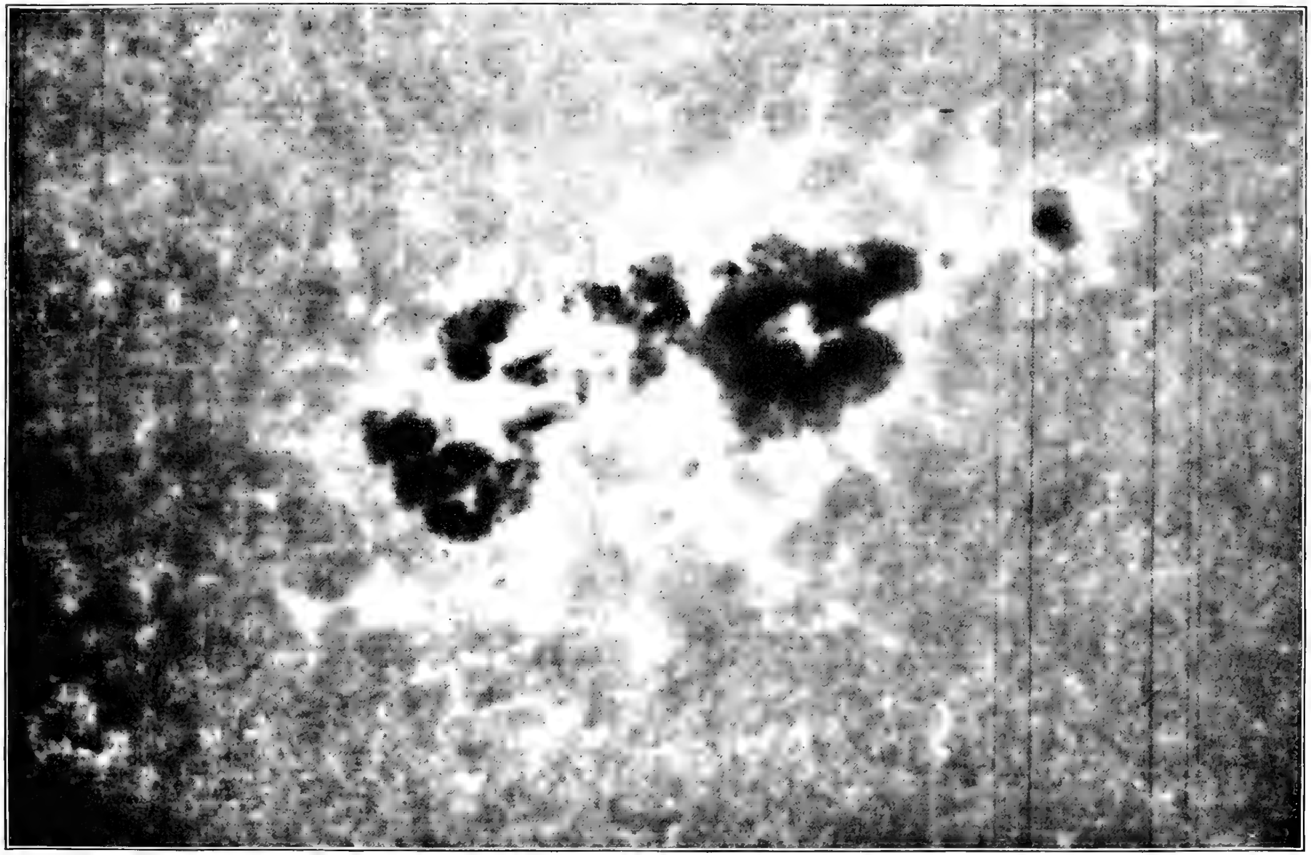
The photograph reproduced in this plate represents the low level flocculi surrounding the spot group, as they appeared on October 10. The changes in the group may be seen by comparing this photograph with Plates XI–XII.



THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, low H_1 level. Slit at λ3962. October 10, $8^h 58^m$. Scale: Sun's diameter 0.565 meter.

N

E  W

S

THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, middle H_1 level. Slit at λ3966.5. October 10, $9^h\ 39^m$. Scale: Sun's diameter 0.565 meter.

PLATE XVI.

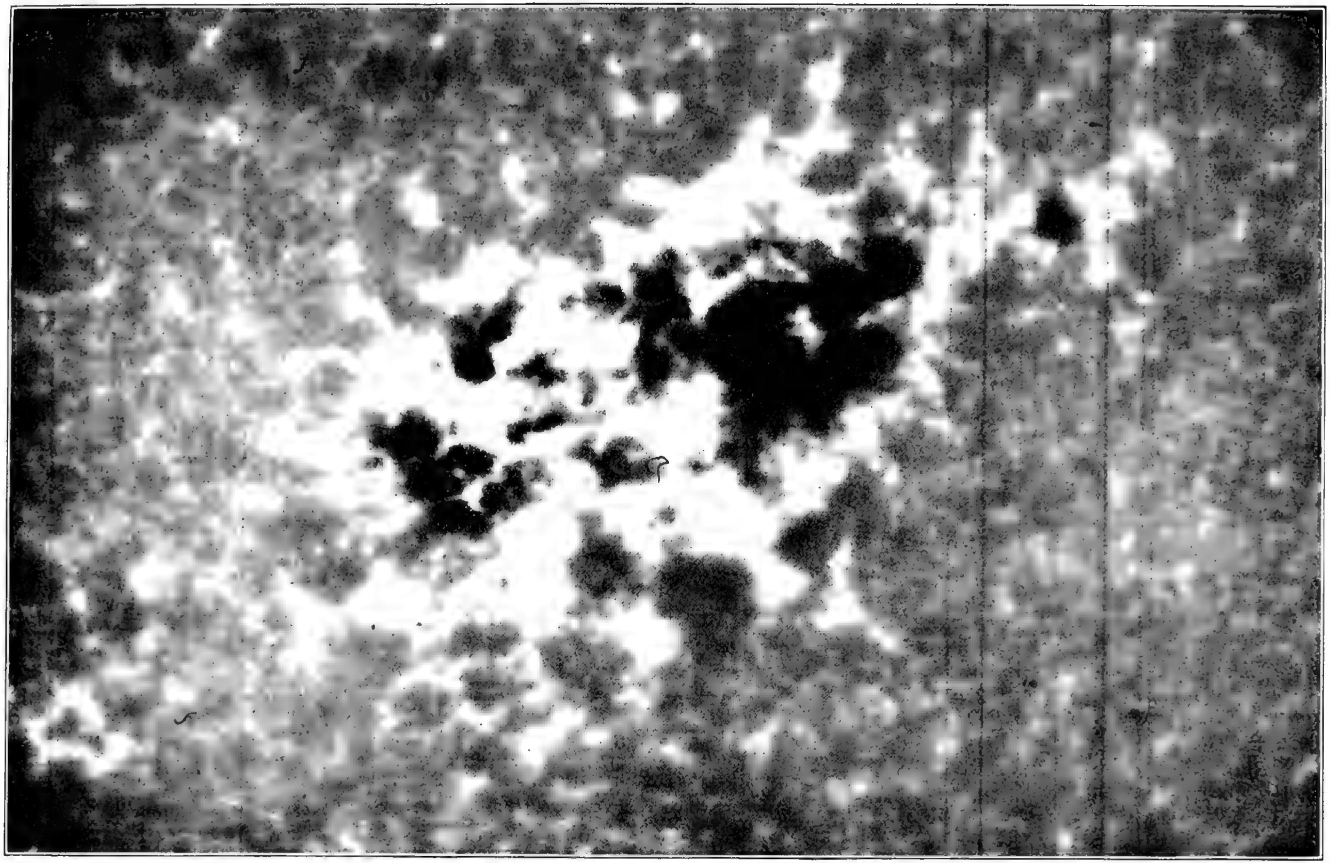
The photograph reproduced in this plate represents the medium level flocculi surrounding the spot group, as they appeared on October 10. The changes in the group may be seen by comparing this photogrpah with Plates XIII–XIV.

PLATE XVII.

The difference in level between Plate XI and Plate XII is too great to permit of a satisfactory study of the changes in form of the flocculi at different heights above the photosphere. In the present series it is fortunately possible to give an intermediate step, obtained by setting the second slit immediately outside of H_2; the level shown therefore lies between that of Plate XV and that of Plate XVIII.

PLATE XVIII.

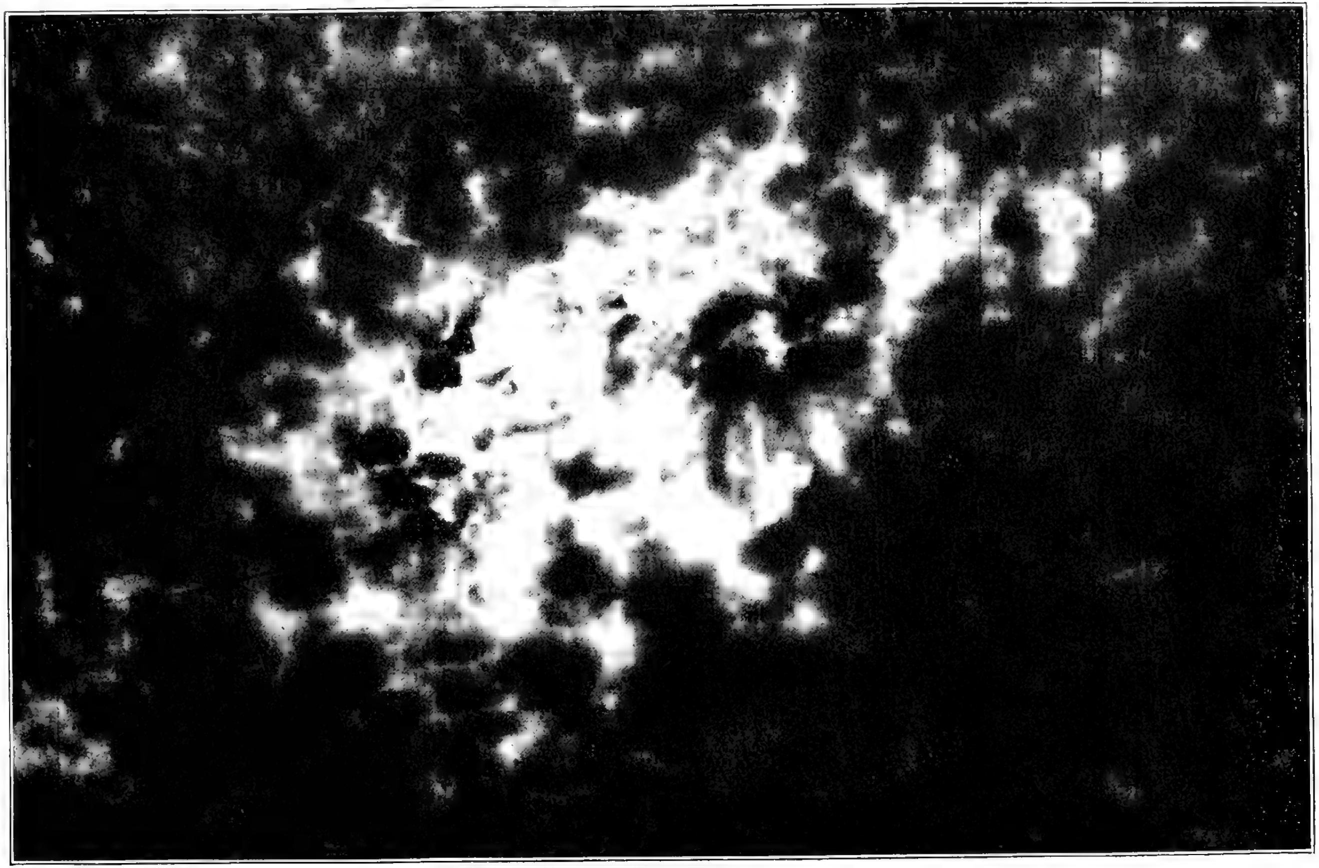
This photograph is given here in the endeavor to bring out the bright eruptive tongues, hardly to be distinguished from the less brilliant flocculi. The abnormally dark background necessarily results from the deep printing required to show the exceedingly brilliant details.



THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, high H_1 level. Slit at $\lambda 3967.5$. October 10, $10^h 59^m$. Scale: Sun's diameter = 0.565 meter.

N

E  W

S

THE GREAT SUN SPOT OF OCTOBER, 1903.

Calcium flocculi, H_2 level. Slit at λ3968.6. October 10, 9^h 09^m. Scale: Sun's diameter = 0.565 meter.

CONSTRUCTION OF LARGE TELESCOPE LENSES.[a]

By Dr. C. Faulhaber.

The three principal instruments for the study of the heavenly bodies are the telescope, the spectroscope, and the photographic camera; and since the two latter are made useful only as they are attached to the former, it is the telescope which we must still regard as the key to unlock the doors of the universe. Readers have all doubtless seen a large telescope, and many have had an opportunity of looking through one, for most observatories reserve certain hours for the public. Accordingly a description of the instrument as a whole may be omitted, and we will merely recall that, notwithstanding it is so long and heavy, complicated mechanical and electrical means are provided for pointing and accurately guiding the telescope, so that it follows automatically the motion of any chosen celestial object. But no less hard than the difficulty of providing these mechanical adjuncts is the optical problem of providing the great double lens called the objective at the upper end of the tube. The objective is the fundamental part of the telescope, on whose excellence the value of the whole instrument depends, and not only its quality but its size also is of the highest importance to make possible the observation of objects otherwise forever invisible. Hence it is that telescopes are designated, not by the maximum magnification which they can produce, nor by their length, but rather by the diameter of their objectives. Thus one speaks of the 40-inch of the Yerkes Observatory, the 36-inch of the Lick Observatory, and the 32-inch Potsdam refractor.

In order to study the construction of a great telescope objective, the attention of the reader is now invited to a great optical glass works, of which there are but three principal ones in the world, namely, those of Schott & Genossen, in Jena; Mantois, in Paris; and Chance Bros. & Co., in Birmingham.

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[a] Translated, by permission, from Prometheus, Berlin, Vol. XV, Nos. 34–35, 1904.

To begin the process of construction a crucible of fire-proof clay, which already has been warmed gradually for several days, is placed within a melting oven of peculiar construction. This oven is then closed and slowly heated to white heat, while at the same time the materials to compose the glass are admitted to the melting pot through a peehole about as large as a man's head in the wall of the oven.

The material varies with the kind of glass to be made. Until the beginning of the year 1880 only two kinds of optical glass were in use, of which one—the so-called crown glass—was composed of quartz sand, potash, soda, and calcspar, and the other—the so-called flint glass—was composed of quartz sand, potash, and lead oxide. There are now more than 100 vareties of optical glass produced by the intermixture of other materials, such as phosphorus, boric acid, magnesium, zinc, barium, antimony, which are distinguished by different properties of dispersion and refraction. The choice of the proper glass for the two lenses depends on the purpose which the telescope is to serve, and particularly whether it is to be employed for visual or photographic observations.

About thirty hours is consumed in the introduction of the matirals. If there be no mishap—for sometimes at the temprature of 1,600° to 1,800° the melting pot cracks or even the stones of the oven burst—the impurities are then skimmed off from the surface, and for about fifteen hours the mixture is stirred by means of a hook-shaped, white-hot clay cylinder.

When the ingredients of the glass are melted they have a tendency to separate in layers according to their specific gravities, and thus to destroy the homogeneity required for optical purposes. This difficulty is chiefly overcome by the continuous stirring of the melted mixture. By repeated tests the moment is at length found when the charge assumes the proper color and degree of fluidity. When this moment arrives the farther side of the oven is opened and a two-wheeled truck with long handles is backed up to the opening. Two projecting pieces of the truck reach out under a ring which is made for this purpose on the clay melting pot, and the latter is carefully lifted from the floor of the oven. On account of the overflow of melted glass, which often cements the pot to the bottom of the oven, this is an operation involving a great risk that the fragile white-hot clay melting pot may break, owing to the shaking required to free it from the oven.

The melting pot is next moved over to a great circular iron mold, and is then set down upon the floor, in order to reenforce the pot with an iron band. On opposite sides of the iron band are steel pins fitting on hooks attached to the truck. By means of this arrangement the pot is lifted above the mold and its contents poured therein.

Contrary to what might perhaps be expected, this process is accomplished with little noise beyond a slight crackiing and rustling sound. This is the culminating point in the whole process of glass making, and gives rise not only among unaccustomed onlookers, but also among the skilled workers themselves to mingled feelings of great anxiety and exalted admiration.

The mold with its fiery contents is then covered with an iron plate and pushed over to the cooling oven, which has in the meanwhile been carefully heated and opened ready to receive the charge. Here the mold is lifted by a tackle and thrust into the cooling oven, where, after the walls have been sealed up as tightly as possible, it remains from four to six weeks undisturbed. Very gradual lowering of the temperature is required, else the cooled mass might burst with the slightest touch, or at least show prejudicial strains in the interior.

When at length the oven is opened the mold is found to contain a solid, feebly lustrous, milk-white plate, which is easily removed from its iron bed.

There now begins a week-long process of grinding and polishing of the glass plate preparatory to a preliminary examination as to its freedom from striæ, bubbles, and conditions of interior strain. Experience shows that in general only a part of such a plate is of optical value. This part is cut out by means of a glass saw and again heated till soft in a crucible, which corresponds approximately with the final form of the objective. After this comes a second gradual cooling during a period of several weeks and another rough polishing and testing of the quality of the resulting plate of glass.

In favorable cases the product is now ready for removal to the optical shop, but commonly there are ten or more unfavorable trials before securing a successful result in the manufacture of a disk of glass for a lens of 1 meter diameter. Since, as we know, there are two such disks of equal size required for a telescope objective, weeks and months of further work are required for the production of the second. The process is in all respects the same, except that somewhat different materials are employed for the mixture, corresponding to the differences in optical properties desired. In outward appearance crown and flint lenses do not differ much, but one is somewhat heavier than the other.

The description just given relates to the most modern methods of glass making as they would now be pursued at Jena in the manufacture of glass disks for a telescope of 1.25 meters aperture. In the older processes it was customary to melt a charge about three times as large as required, and after this had reached the proper color and consistency, to allow the melting oven to cool slowly and thus to take the place of the special cooling oven. On opening the oven the glass block would be found broken in several pieces, and if there was

none among these which would answer the purpose the process would then be repeated. When a rough block of suitable size and quality was obtained it was put in a crucible of about the proper lens form. The whole was then again melted and cooled and then polished for testing. As an example of the cost in time spent in this procedure, it will be recalled that the Paris glass works required four years for the production of the two lenses of the 36-inch Lick objective. The melting was done twenty times, and each time a month was spent in the cooling. On the other hand, the Jena glass works employing the improved processes, prepared both disks of the slightly smaller Potsdam 80-centimeter objective in a few months.

It may be of interest to rehearse briefly the story of the rapid development of the industry of optical glass making in Germany, principally during the last ten years.

The pioneer in the production of glass for astronomical purposes, according to purely scientific methods, was the renowned Joseph von Fraunhofer, of Munich (1787–1826). But it is only twenty years since Professor Abbe and the glass manufacturer, Doctor Schott, of Jena, took up the work where Fraunhofer laid it down, and succeeded in replacing the old flint and crown glasses by new varieties of glass, by means of which the chromatic differences of spherical aberration are nearly eliminated. The production of the new glasses on a commercial scale began in the autumn of 1884. In order to support the very costly preliminary experiments, the Prussian Government made considerable grants of money in consideration of the national value of the work. This governmental support was required but two years, for the undertaking progressed favorably and the productions found recognition almost immediately in the whole optical world, so that soon not only German, but foreign optical establishments, placed most of their orders for material in Jena. Not only are the common crown and flint glasses made here, but also a great number of improved crown and flint glasses, containing boric and phosphoric acids, to diminish the secondary spectrum on the one hand, and on the other containing metallic oxides, by means of which the dispersion and refraction may be increased or diminished. An extensive exhibition of these products was witnessed by the visitors who attended the Berlin Gewerbe-Ausstellung in 1896. There were shown disks for the construction of telescopic objectives of 110 and 125 centimeters diameter, and these were the largest pieces of optical glass which had then been made. Not only is optical glass produced for all kinds of instruments of precision, but also there is made at Jena glass tubing for physical, chemical, manufacturing, and medicinal purposes, and all sorts of chemical glassware, such as flasks, beakers, and retorts, besides cylinders for gas and petroleum

lighting. There are now employed in this industry about 650 persons, and the value of the yearly output reaches 3,000,000 marks.

We are now prepared to trace to the further stages in the preparation of a great objective, and the attention of the reader is invited to the optical workshop. Here the glass disks are first ground and polished on both sides preparatory to a thorough testing. For this purpose there is a machine with a vertical spindle carrying an iron plate.

Upon this plate the glass disks are in their turn cemented with pitch, and above is a second iron plate, the grinder, provided with a spindle in the center. By means of this spindle the grinding plate is shoved hither and thither over the glass disk by machinery. The grinding material is emery powder and water. After the rough grinding is done the rough polishing on the same machine follows similarly, excepting that the grinding tool is replaced by a cloth-covered polishing tool, covered with rouge instead of emery.

After this preliminary work, a careful investigation of the disks is made in the laboratory by the aid of the microscope and polarization apparatus. If the objective is good it must appear bright in the polariscope, with the exception of being marked by a regular dark cross. If an irregular cross is seen or, in certain conditions, brightly colored figures of various shapes, the disk must be returned to the glassworks to be remelted and cooled.

In case of a satisfactory outcome of these tests small pieces are cut off and prisms are prepared from them, whose refractive indices are determined by means of the spectrometer. Upon these measurements are based the accurate computation of the objective—that is to say, the determination of the four radii of curvature and the thickness—a tedious piece of work which requires repeated independent checking.

After this begins the real preparation of the objective lenses, one of which is to be ground concave, the other convex, on the same machine which was used in the rough grinding. This present procedure is similar to that already described, except that grinding tools opposite in curvature to the lenses and made of iron, brass, or glass are fed with finer and finer emery powder as the work approaches its finish.

Since everything depends on the proper guiding of the grinding tool to obtain the regular spherical surfaces, the operating of the machine demands great experience and care, and the work requires frequent testing by the application of the spherometer. When finally the right curvature is reached, after many days of work, repeated and accurate testing of the lens is made by the Toppler "Schlieren-methode" for small errors, nonhomogeneity, and other faults.

The fine-ground lens is now put upon a lathe and centered by means of a fine adjusting crane. This centering consists of shifting the

lens about upon the spindle of the lathe until exact coincidence is reached between the optic axis (common axis of curvature of the two surfaces) and the mechanical axis of the spindle. Recognition of this condition depends on observing the reflections from the two glass surfaces, and accurate centering is reached when these reflections do not move with the rotation of the spindle. When the right adjustment is made the edge of the disk is turned off true by means of a grinding band fed with emery and water, and by this means the lens is reduced to the proper diameter.

After the centering follows the fine polishing on a special polishing machine. The process is much the same as that of rough polishing, excepting that instead of a cloth-covered tool there is provided for each face a series of great pitch-covered plates. Frequent trials of the surfaces are made by means of so-called "test glasses." These are small glass plates ground and polished accurately to fit the desired curve; that is to say, convex for a concave surface, and vice versa. Their employment in testing depends on the following principle: If two closely fitting polished surfaces are laid one upon the other there is retained between them a thin film of air which exhibits the so-called "Newton's colors," seen in soap bubbles and similar thin transparent structures. The color is the same over the whole surface only when the thickness of the inclosed film is everywhere uniform, which only occurs when the lens has the same curvature as the test glass. At the beginning of the polishing the Newton's colors appear as rings of more or less width. By the proper use of polishing tools of different sizes, and by suitable regulation of the stroke and velocity of the machine, the condition is finally reached when a uniform color supersedes the rings, no matter where the test glass is laid upon the lens. By such methods of measurement in terms of the wave length of light, deviations of thickness of only one ten-thousandth millimeter (one two-hundred-and-fifty-thousandth inch) can be accurately detected, a magnitude scarcely appreciable to the lay mind. It is obvious that the fine polishing in such conditions is an exceptionally difficult task, the more so that care must always be exercised to avoid all blemishes on the surfaces, such as scratches and the like, and only the most competent and experienced workers can succeed with it. A conception of the difficulties to be overcome may be found when it is said that the fine polishing of a single lens surface takes several months.

When both lenses have passed through the processes of fine grinding and polishing they are inserted in brass or iron mountings which have meanwhile been prepared for them and in which they lie separated by a small free space. Cementing together with Canada balsam or turpentine, as generally practiced with small lenses, and formerly with large ones also, has more recently been discontinued on account

of the difficulty of separating large cemented lenses for subsequent cleaning.

After the lenses have been placed in their cell there remains only the final testing in the telescope tube itself. I shall not describe the complicated centering apparatus employed in this test. The errors of an objective and their causes are numerous, and their discovery and correction demand great experience and skill.

In conclusion, we may inquire where the telescopes of largest objectives are located, and by whom they were made. In the first place, there is the objective made for the Paris Exposition of 1900, but not among the telescopes in present use. It is 1.24 meters in diameter, and the glass alone weighs 580 kilograms, of which the convex lens weighs 360 and the concave lens 220 kilograms. The cost of the two lenses was 75,000 francs. These disks were poured by Mantois and ground by Martins, both of Paris. Up to the present time the objective has not been usefully employed. The second and third places, as regards size alone, are taken by the objectives of the Yerkes Observatory, near Chicago (1897), and that of the Lick Observatory, at Mount Hamilton, Cal., with diameters, respectively, of 105 and 91 centimeters. Both were poured at the Paris glass works and figured by Alvan Clark in Cambridgeport, Mass.

They are both satisfactory, though not prepared entirely on the basis of computation, but rather by repeated trials, and brought to their completion by the so-called method of local correction. After them in size comes the great refractor of the Potsdam Observatory, prepared solely for celestial photography and having a diameter of 80 centimeters. This objective was poured in Jena and figured at the optical works of C. A. Steinheil Söhne, in Munich, in 1899. It is recognized to be of the highest order of merit and is a strong testimony to the ability of German manufacturers in this line. The Potsdam refractor has, in addition to the 80-centimeter photographic lens, a second visual lens of 50 centimeters diameter, and being thus a double refractor is perhaps the largest astronomical instrument in use in the world. Both of the great American telescopes are devised solely for visual purposes, and can only be used for photography by the aid of auxiliary lenses which cut off some of the light.[a]

Among other large objectives may be enumerated the Pulkova refractor, at St. Petersburg, by Clark, diameter 76 centimeters; objective of the Observatory of Nice, of equal diameter, by Henry Brothers, of Paris; the objective of the Vienna Observatory, of 71 centimeters aperture, by Martins, and the Treptower objective, of 70 centimeters

[a] The Yerkes telescope is used as a photographic instrument by interposing in front of the plate a color screen for removing the violet rays and exposing plates sensitive for the yellow rays.

aperture, poured at Jena, ground in Munich (1896), and costing 55,000 marks.

The objective of the Dorpat refractor, with 25 centimeters aperture, which, as it came from the master hand of Fraunhofer, was regarded as a wonder of the world, can scarcely be counted among the large telescopes to-day, for already more than 100 exceed its dimensions. It would lead too far to mention them all, but it is not out of place to remark that there is work of great value also for the smaller lenses. Interesting studies of the features of the planets have been made even in recent times with smaller instruments. Thus Schiaparelli, the famous discoverer of the so-called Martian canals, made his earlier valuable observations with an 8-inch telescope, which would now be classed as a minor instrument. In planetary observation the advantages of fine optical definition, together with good atmospheric conditions, combined with practiced eyes, are of more consequence than high power or great light-gathering capacity. The advantages of the largest instruments lie in the possibilities they afford of observing the fainter fixed stars and nebulæ which lie at immeasurable distances.

SOME REFLECTIONS SUGGESTED BY THE APPLICATION OF PHOTOGRAPHY TO ASTRONOMICAL RESEARCH.[a]

By H. H. Turner, D. Sc., F. R. S.

It is a familiar fact that there are epochs in the history of a science when it acquires new vigor; when new branches are put forth and old branches bud afresh or blossom more plenteously. The vivifying cause is generally to be found either in the majestic form of the discovery of a new law of nature or in the humbler guise of the invention of a new instrument of research. The history of astronomy has been rich in such epochs, notable among them being that when Newton announced to the world the great law of gravitation, and that when Galileo first turned his telescope to the skies.

We have within the last half century been fortunate enough to include another great epoch in astronomical history, characterized by the birth, almost a twin birth, of two new scientific weapons—the spectroscope and the sensitive film. It is, of course, somewhat difficult and scarcely necessary to assign an exact date for the origin of either of these. The spectroscope was perhaps first systematically used on the heavenly bodies by Huggins, Rutherfurd, and Secchi in the fifties, but we may trace it back to the early work of Fraunhofer, who described the spectrum of Sirius in 1817, or further back to the experiments of Newton with a prism; and the dry plate, which in particular has conferred such benefits on our science, had of course its precursors in the collodion plate or the daguerreotype. But the greater part of the influence on astronomy of both the spectroscope and the photographic method dates from the time when the dry plate was first used successfully, not much more than a quarter of a century ago; and in that quarter of a century there have been compressed new advances in our knowledge which perhaps will compare favor-

[a] Address delivered by H. H. Turner, D. Sc., F. R. S., Savilian professor of astronomy in the University of Oxford, in the section of astrophysics at the Congress of Arts and Sciences at St. Louis, on Wednesday, September 21, 1904. Reprinted from the Obesravtory, London, November-December, 1904.

ably with the work of any similar period in centuries either past or to come. It is difficult to estimate at their true value historical events in which we play a part, and any review of such a period undertaken now must be necessarily imperfect, for we are advancing so rapidly that our point of view is continually changing. But it is an encouraging thought that obvious difficulties may enhance interest in the attempt and suggest kindly excuses for its shortcomings.

From the embarrassingly large number of possible topics which the period provides I have selected that of astronomical photography, and I invite your attention to some characteristic features of the photographic method in astronomy, and some reflections thereupon. It is scarcely possible to avoid repeating much that has been said already, but I hope it will be clear that no claim to originality is advanced. In what follows I wish to claim nothing as mine save its imperfections.

The advantages of the photographic method, which attracted attention from the first, may be grouped under three heads—its power, its facility, and its accuracy. The lines of demarcation are ill defined, but the classification will help us a little, and I proceed to consider the groups in this order.

The immense power of the photographic method as compared with the eye arises from the two facts that (*a*) by the accumulation of long exposures fainter and fainter objects can be detected, and that (*b*) large regions of the heavens can be recorded at the same exposure. No property of the photographic plate has excited more marvel than the former—that it can detect objects too faint to be seen even by our largest telescopes; objects of whose very existence we were in ignorance and should have remained in ignorance. Early successes have been followed up by others more striking as years have rolled on, as better instruments have been devised, and the patience of the watchers has proved equal to greater strain. It is here that the change from the "wet" plate to the "dry" has proved most advantageous. The possibilities with the former were limited to the period during which it would remain wet; with the latter, exposures may be continued for hours, days, even years—not, of course, continuously in the case of astronomical photography, for the camera must be closed when daylight approaches; but it can be opened again at nightfall and the exposure resumed without fault. In this way objects of extraordinary faintness have been revealed to us. When Nova Persei had flashed into brilliance in 1901, and then slowly faded, long-exposure photographs of its region revealed to us a faint nebulous structure which we could never have seen; they told us that this structure was changing in appearance in a manner which it taxed our ingenuity to explain, and about which speculation is still rife. But a greater triumph was to come;

even the spectrum of this faint object has been photographed. When we consider that in the spectrum each point of light in the object is enormously diluted by being spread out into a line, the difficulty of this undertaking seemed almost prohibitive; but it was not sufficient to prevent Mr. Perrine, of the Lick Observatory, from making the attempt, and he was deservedly rewarded by success. I may be wrong in regarding this success as the high-water mark in this direction at the present time, and it will probably be surpassed by some new achievement very shortly; but it will serve to illustrate the power of photography in dealing with faint objects.

But may we here pause for one moment to marvel at the sensitiveness of the human eye, which is such that it is, after all, not left very far behind in the race? The eye, sensitive as it is merely to transient impressions, is no match ultimately for the plate, which can act by accumulation. But with similar instruments the plate must be exposed for minutes or even hours to seize the impression of a faint object which the eye can detect at a glance. There seems to be no reason in the nature of things why the eye should not have been surpassed in a few seconds; and in the future the sensitiveness of plates may be increased so that this will actually be the case, even as in the past there was a time when the sensitiveness was so small that the longest exposure could not compete with the eye. But this time is not yet come, and at the present moment the eye is still in some departments superior to its rival, owing to this very fact, that though it can only see by glances, it can use these glances to good effect. In the study of the planets the more clumsy method of the photographic plate (which, by requiring time for the formation of the image, confuses good moments with bad) renders it almost useless as compared with the eye; and again, we have not as yet used photography for daylight observations of stars.

But there is another direction in which the photographic plate is immensely superior to the eye in power; it can record so much more at once.[a] In the able hands of Professor Barnard, Dr. Max Wolf,

[a] This property has been beautifully illustrated by a lecture experiment of Professor Barnard. He throws on the screen a picture of a large nebula which the photographic plate has no difficulty in portraying all at once; but the picture is, in the first instance, covered up by a screen, except for a small aperture only, and this aperture, he tells his audience, represents all that can be seen by the eye at one time, using the giant telescope of the Yerkes Observatory. By moving the screen about, different portions of the picture may be viewed successively, as also by moving the telescope about in looking at the sky itself. But what a revelation follows when the screen is removed and the full glory of the nebula is exhibited at a single glance! We can well understand that the true character of these objects was hopelessly misinterpreted by the eye using the imperfect method of piecemeal observation, which alone was formerly possible.

and others, this property of the plate has been used to record the presence in the sky of vast regions of nebulosity such as, we may safely say, the eye would never have satisfactorily portrayed, not altogether because of their faintness (for in one of his papers Professor Barnard tells us that he was actually led to photograph such a region because he had become vaguely conscious of it by eye observation), but because of their diffusion. It is noteworthy that these beautiful photographs were taken with comparatively humble instruments, and we may be as yet only on the threshold of revelations still to be made in this direction.

Secondly, the photographic method represents a great advance in facility of manipulation. A familiar example may be taken from the domain of planetary discovery. In old time to recognize a new object among numerous fixed stars it was necessary either laboriously to map out the whole region, or to learn it by heart, so that it was practically mapped in the brain. Now all this labor is avoided; two photographs of the same region, taken without any strain on the memory or the measuring ability of the observer, can at a glance, by a simple comparison, give the information that a strange object is or is not present—information formerly obtained at so much cost. Sometimes, indeed, the cost was so great that the information was not obtained at all. For fifteen years Hencke searched without success for a planet, and for nearly forty years after the discovery of the first four small planets, in 1807, no further discoveries were made, though hundreds were constantly crossing the sky, and a dozen new planets are now found every year with little trouble.

But though this instance of increase in facility is striking, it is far from being the only one or even the most important. Wherever we require a record of any kind, whether it be of the configuration of stars, or of solar spots, or of the surface of the moon, or of a spectrum, the labor of obtaining it has been enormously reduced by the photographic method. Think for a moment of what this means in the last instance only—think of the labor involved in mapping one single spectrum by eye observation; of the difficulty of settling by such a method any doubtful question of the identity of certain lines in the spectrum of a star. A few years ago Doctor McClean announced that he had found oxygen in the star β Crucis. Up to that time this element, so familiar to us on this earth, had appeared to belong to us alone in the universe, for in no spectrum had its lines been detected. The proof of its existence in β Crucis depended on the identity of a number of lines in the spectrum with some of those of oxygen; and the measures were sufficiently difficult on a photograph, so that for more than a year the scientific world refused to pronounce a verdict. How long would the case have dragged on if only visual measures had been possible? We may fairly doubt

whether a definite conclusion would ever have been reached at all. By the sheer facility of the new method of work we have advanced by leaps and bounds where we could only crawl before.

Thirdly, there has been a great gain in accuracy from the introduction of photography; and it is this quality which is above all of value in the science of astronomy.[a] The wonderful exactness of the photographic record may perhaps best be characterized by saying that it has revealed the deficiencies of all our other astronomical apparatus—object glasses and prisms, clocks, even the observer himself.

It has almost been forgotten that in the early days the accuracy of a photograph was doubted. Even now it can scarcely be said that we know definitely the stage of refinement at which we must begin to expect irregular displacements of the images from distortion of the photographic film; but we have learned that they do not occur in a gross degree, and that other apparatus must be improved before we need turn our attention seriously to errors arising from such a cause. Consider, for instance, what photography has told us about our optical apparatus, which we regard as having reached a high state of perfection. We are accustomed to think of properly made optical apparatus as being sufficiently similar in all its parts; it is tacitly assumed in the principle of the heliometer, for example, that one half of the object glass is sufficiently similar to the other. But a stock adjustment recently adopted in photographing a spectrum for accurate measurement exhibits clearly the errors of this assumption. Photographs are taken of the spectrum through the two halves of the objective; and if they were properly similar the lines in the two halves of the spectrum should fit exactly. A mere glance is usually sufficient to show discordances. It is true that one of the photographs is taken through the thick half of the prism and the other through the thin, so that errors of the prism are included; but these, again, are optical errors. They are, however, not the only sources of error which at present mask photographic imperfections. Glass plates are not flat, and this want of flatness introduces sensible errors. Even with the great improvements in our driving clocks which were called for immediately photographs were to be taken—with electrical control and careful watching on the part of the observer—there is apt to creep in a "driving error" which gives bright stars a spurious displacement relatively too faint. We must get flatter plates, better driving clocks, and watch more

[a] Two things may be measured on a photographic plate—the position of an object, or the density of the image; the former being an indication of its position in the heavens, and the latter of its brightness. With the latter topic I do not propose to deal, for the reason that it is in the hands of a much abler and more experienced exponent; but the former alone will provide enough food for reflection.

carefully before we can certainly accuse our photographs of a failure in accuracy. Nevertheless, there are indications that we may be near the limit of accuracy even now. Examination of the réseau lines on various plates appears to show small displacements for which no cause has yet been assigned; and the end of our tether may not be far away. But as yet we have not been pulled up short, and there is hope that the warning may be, as on one or two previous occasions, a false alarm.

Such being the accuracy of the photographic method, it is surprising that it should not as yet have been more fully adopted in that field of work where accuracy is of the greatest importance—namely, in what is called fundamental work, with the transit circle or other meridian instruments. The adoption of new methods is always a slow process, and there are at least two classes of difficulties which hinder it. The first class has it origin in the instinctive conservatism of human nature, wherein men of science differ little from their fellows. The second has to do with available capital; and in this respect we are distinctly at a disadvantage compared with other men; for when a new instrument of general utility is invented at once a large amount of capital is invested in working out the details and improving them to the utmost, whereas for a scientific instrument no such funds are available. Think, for instance, of the money spent in perfecting the bicycle, and the time occupied in developing it from the earliest forms to those with which we are now familiar—from the "bone shaker" of the sixties through the high bicycle which we saw twenty years ago to the modern machine. Think, too, how totally unexpected have been some of the incidents in the history of this machine, such as the introduction of pneumatic tires. In the case of such an instrument, now universally adopted, if rapid development could have been secured by expenditure of money and brains, surely enough of both commodities were forthcoming to attain that end; and yet simplicity and finality have probably not yet been attained in a period of thirty years. When we compare the small amount of money and especially the small number of persons that can be devoted to the perfection of a new scientific method, such as the use of photography in astronomy, it will excite little surprise that progress during the same period of thirty years has been slower. In commerce old machines can be thrown on the scrap heap when improvements suggest themselves; but who can afford to throw away an old transit circle? The very fact that it has been in use for many years renders its continued use in each succeeding year the more important from considerations of continuity.

It is doubtless for such reasons as these that little has yet been done in the way of utilizing photography for meridian observation.

Although one or two meritorious beginnings have been made, which have sufficed to show that there are no insuperable difficulties in the way, up to the present moment no meridian instrument of repute is in regular work using the photographic method. And this fact can not, after all, be completely explained by the reasons above mentioned. Opportunities for setting up costly new instruments do not occur frequently in astronomy, but they do occur. In the last decade, for instance, large transit circles have been set up both at Greenwich and the Cape of Good Hope; but in neither instance has any attempt been made to adopt the photographic method. The Washington Observatory was reconstructed well within the period since the great advantages of photography have been recognized, and yet not even in the United States, the land of enterprise, was a start then made in a direction in which it is certain that we must some day travel. That day has probably been deferred by the stimulation of competing methods which a new one brings with it. When electric light was first introduced into England the gas companies, stimulated by the stress of competition, adopted a new and improved form of light (the incandescent gas) which put them at a much less serious disadvantage compared with their new rival. So when photography began to show what new accuracy was attainable in measurement of star positions, it would almost seem as if the devotees of the older visual methods were compelled to improve their apparatus in order not to be left wholly behind in the race. The registering micrometer[a] was

[a] We have been accustomed hitherto to determine the position of a star by observing the instant when it crossed a fixed wire; but it has long been known that two different observers record systematically different instants—they have a personal equation. Recently we have learned that this personal equation varies with the brightness of the star observed, and with other circumstances, and to make the proper corrections for it has severely taxed our ingenuity and involved much work. Before the invention of photography we might well bear this with patience, since it seemed to be inevitable; but the photographic plate which is free from human errors, offers a way of escape from all troubles, at the expense, no doubt, of some little experimenting, but with every prospect of speedy success. Eye observation, which had borne this burden so long, must get rid of it if it was to march alongside the untrammeled photographic method; and the surprising thing is that it has actually done so. The adopted device is extremely simple: Replace the fixed wire which the star crosses by a wire which moves with the star and registers its own movements. The registering is done automatically, but the motion of the wire is controlled by the observer, and there is still room for a new form of personal equation in this human control. But none manifests itself, probably for the reason that we no longer have two senses concerned, but only one. In recording the instant when a star crosses a wire we employ either the eye and the ear, or the eye and the sense of touch, and personal equation arises from the different coordination of the two senses in different people. But in making the wire follow the star the eye alone is concerned, and there is no longer any room for difference in "latent period" or other coordination of two senses.

produced by Messrs. Repsold, with the astonishing result that the troubles from personal equation, which have so long been a difficulty in all fundamental work, have practically disappeared.

This beautiful invention has placed the eye once more in a position actually superior to the photographic plate, for with the eye we can observe stars in daylight, and so secure information of great importance, whereas no photographic method of doing this has as yet been devised. And there is also the fact that for faint stars a long exposure would be required for what the eye can accomplish in a few seconds.

Thus in one or two astronomic channels the effects of the rising tide of photography have scarcely yet been felt; but into all the others it has swept with ever-growing force. Looking back over the thirty years of advance, we may be well satisfied. With more funds, and especially with more men, no doubt more could have been done; let us even admit that we might have done better with the same funds and the same limited staff. But on the whole we have been fortunate. At a critical time, when we might have felt the want of larger endowments acutely, the need was almost anticipated by a stream of benefaction. If this stream had its chief source in the United States, its beneficial effects have poured over the whole world, and induced currents have begun to flow elsewhere. We may reflect with thankfulness how much harder our advance might have been but for the noble gifts to the Harvard, the Lick, and the Yerkes observatories, and earnestly hope that the cheerful expectations of a great American astronomer, that these are but the foreshadowing of much larger gifts to science, may be adequately realized.

May I now turn to one or two of the problems with which this new development of our work has brought us face to face? They are numerous and serious, and it is impossible to consider many of them, perhaps even the most important of them. One of the most pressing is the problem of rendering generally accessible the vast accumulations of material for study that have been suddenly thrust upon our attention. How are our photographs to be stored, preserved, and published? Even now troubles have gathered, and time will only multiply them. It is many years since Professor Pickering drew attention to the difficulties in storing the photographic plates taken at the Harvard Observatory. When many thousands of photographs have been accumulated, not only the space they occupy, but the actual weight of glass is an embarrassment. And there seems to be no doubt concerning the duty of accumulation. May I confess an early and mistaken view which I formulated on this matter? I reasoned thus: The proper moment for making use of a photograph taken last night is to-day. It is useless to defer the examination until to-morrow, for there will then be new photographs claiming attention. Hence it is

unscientific to take more photographs than can be dealt with immediately. This seemed to be a plausible argument and to show a way out of the difficulty, for if a photograph had once been adequately examined it need not be stored so carefully, and there would not in any case be many to store. But Professor Pickering has demonstrated many times over that the view is untenable. By taking photographs almost recklessly and without any hope of dealing with even a fraction of them, he has created the possibility of tracing the history of celestial events backward. When new objects are discovered he can go to his shelves and tell us how long they were visible previous to discovery; and this information is so valuable that we must certainly arrange our future plans with reference to it. It is quite certain that we must be prepared to deal with enormous accumulations of plates, to store them in proper order, and to catalogue them; and if it has already been found difficult to do this for the collection of a single observatory during twenty years, what can we look for in the centuries to come?

Possibly the second difficulty, that of preservation, may be an antidote to the first. It is by no means certain that our photographs will last long, and if not there will be a natural limit to the time during which they need be kept. Sir William Crookes has, however, reminded us that by toning them, by substituting sturdy gold for the perishable silver, we may prolong their life indefinitely, though this will, of course, sensibly increase the cost of each plate. As yet I have not heard of any toning process being systematically adopted. Our course is, however, comparatively clear in this direction. It would seem imperative that a selection of the earliest photographs, at any rate, should be carefully toned, so that they may be available for comparison in years as far distant as possible. Although this is a matter of detail, it seems to me to compare in importance with almost any practical question which may claim the attention of astronomers, and if some decision of the kind were the only outcome of this gathering I think we might be well content with the result.

The question of publication is chiefly one of funds, and is only worthy of special remark because these particular funds are so often forgotten in planning enterprises. I need not labor the point, for the experience of any astronomer will supply him with plenty of instances. The difficulties of publication have much in common with those of storage. They will increase year by year, and even when the money for printing has been found the storage of publications received from other observatories will itself become an embarrassment. There is, however, one way in which some of the stress may be relieved, namely, by efficient cataloguing. If we have before us a list of all the photographs existing in the world, and know that we can send for a copy of any one of them which may be required, it is no

longer necessary to have copies of all. This applies, of course, to other publications as well, and though we may take some time to grow out of the sentimental desire for a complete library, and though the existence of a few such complete institutions may always be desirable, I venture to think that many observatories will ultimately be driven to the plan of acquiring only what is certainly and immediately useful, depending on temporary loans from central institutions for other material.

But there is a class of problems differing totally in character from these practical questions of storage and preservation of plates. A period of suddenly increased activity such as we have been passing through in astronomy is not without important effects on astronomers themselves. The human element in our scientific work is sometimes overlooked and generally accorded only a subordinate importance; but, coming as I do from an old university devoted to the humanities, I may be perhaps forgiven for calling attention to a few human considerations. In the first place, I have felt some anxiety lately for that very important body of astronomers who are sometimes called "amateurs," though the name is open to criticism—those whose opportunities for work are restricted to a more or less limited leisure. It is a body which is somewhat sensitive to the feeling that astronomical work has gone beyond them; that in the presence of large instruments and of the special knowledge acquired by those using them their own efforts and their own humbler instruments are no longer of any value. If I am right in supposing that this feeling has been called into existence lately by the rapid advances made in photography, it is certainly not for the first time. At previous epochs this diffidence has found expression, and has, I am glad to say, been met by careful contradiction; but it is necessary to repeat the expostulation again and again, for the anxiety is apt to crop up with every new development of astronomical activity.

The earlier days of photography were better ones than usual for the amateur; indeed, the introduction of the photographic method is largely due to the work of such men as Rutherfurd and Draper in America, De la Rue and Common in England. But now that we have passed beyond the stage when each new plate taken was a revelation; now that we are tolerably familiar with, at any rate, the main types of possible photographs which can be taken with modest apparatus; more especially now that we have begun to discuss in elaborate detail the measurement of star positions or of stellar spectra, the old shyness is beginning to crop up again. But it is of the utmost importance that this shyness should be zealously overcome. Perhaps, after all, it is not sufficient to assert that there is still good work for amateurs to do, nor even to mention a few instances of such work urgently required; perhaps it should be made easier for them to follow what is

being done. Especially do we want more and better books, written by the best men on each subject. The original memoir, though it may be the proper form of publication for the workers themselves, does not satisfy all requirements. There is much to be done in the way of extension and collation before the work can be presented in a form attractive to those who would gladly keep in touch with it if the process could be made a little easier. Huxley was constantly urging scientific men that it was not sufficient to attain results; they must also express them in an intelligible and attractive form. Of course it is not easy for the same man to do both. There are few who could have determined, like Schiaparelli, that the period of rotation of the planet Mercury was eighty-eight days instead of one, but there are fewer still who, after making the discovery, could have given the beautiful lecture which he gave before the King of Italy, developing fully in attractive detail the consequences of the discovery; and yet it is probably true that many more could make, at any rate, an attempt in this direction if adequate opportunity and inducement were provided. Could not a part of the sums available for the endowment of research be devoted to the endowment of text-books? It is, of course, an inducement to write such a book that it is a good thing well done; but in the case of a scientific worker this is scarcely sufficient, because the same could be said of his continuing his particular work. If we ask him to pause and render the treasures he has collected accessible to others there must be some additional inducement. Publishers are not able to offer pecuniary encouragement, because books of the type I have in mind would not appeal to a very large public. But why should they not be subsidized? I do not think it need be a very costly business, if the money were placed in the hands of a central body to issue invitations for books to be written. An invitation would be in itself a compliment, and the actual pecuniary value of the inducement would shrink in importance, just as the actual amount of gold in a medal awarded by one of our leading scientific societies is not very seriously regarded. It may be objected that to ask the best men to write text-books is to set them to inferior work, and so to delay true scientific progress; but are we sure that the real march of science is being delayed? There are pauses in a journey which merely waste time, but there are others without which the whole journey may be delayed or prevented, as when a man should neglect to rest and feed the horse which carries him.

But the development of photography has brought with it much more than a recurrence of diffidence in some amateurs; it has foreshadowed a serious rearrangement of astronomical work generally—a new division of labor and a new system of cooperation. To quote one notable instance, a very small number of observatories could take enough photographs to keep the whole world busy examining or meas-

uring them, and we are already face to face with the question whether this is a desirable arrangement. Let me give a concrete example of this modern situation. In the winter of 1900–1901 the small planet Eros offered a specially favorable opportunity for determining the solar parallax, and some thousands of photographs were taken at a number of observatories for the purpose. It is not yet very clear how a definitive result will be obtained from the mass of material accumulated, most of which is being dealt with in a very leisurely manner; but a small portion of it has been discussed by Mr. A. R. Hinks, of Cambridge, and one of the many important results obtained by him in a recently published paper (Mon. Not. R. A. S., June, 1904) is this: That the plates taken at the Lick Observatory are susceptible of such accurate measurement, and so numerous, that a determination of the solar parallax from them alone would have a weight nearly equal to that from the whole mass of material. If the Lick plates can be measured and reduced, it will not much matter if all the others are destroyed. Whence we may deduce two conclusions: Firstly, that it is eminently desirable that these beautiful pictures should be measured and reduced as soon as possible; secondly, that we must consider future plans of campaign very carefully if we are to avoid waste of work and discouragement of workers. It is tolerably easy to reach the first precise conclusion. I wish it were easier to arrive at something more definite in regard to the second. It seems clear that we may expect some readjustment of the relations between the better-equipped observatories and those less fortunate, but it is not at all clear what direction that readjustment should take. One possibility is indicated by the instance before us. The discussion of the Lick photographs was not conducted at the Lick Observatory, but at Cambridge. The price paid for the fine climate of Mount Hamilton is the accumulation of work beyond the powers of the staff to deal with, and the new division of labor may be for the observatories with fine climates and equipment to take the photographs and astronomers elsewhere to measure and discuss them. Professor Kapteyn has set us a noble and well-known example in this direction, and in view of the pressing need for a study of many photographs already taken, it is to be hoped that his example will be followed, especially in cases similar to his own, where no observatory is in existence. If in such cases the investigator will set up a measuring machine instead of a telescope, he will deserve the gratitude of the astronomical world.

But the case is not so clear when a telescope is already in existence. Mr. Hinks had a fine telescope at Cambridge, and it required some self-denial on his part to give up observing for a time in order to discuss the Lick photographs and others. If the accumulations already made, and others certain to be made in the future, are to be dealt with, this kind of self-denial must certainly be exercised,

but it does not seem quite clear that it should always fall to the lot of those with a modest equipment. Considerations of strict economy might suggest this view, but there is a human side to the argument which is not unimportant. The danger that the minor observatories should feel their work unnecessary is even graver than the similar possibility in the case of amateurs already mentioned, and calls for prompt attention from astronomers generally if it is to be averted. It is the more serious because of another set of considerations of a quite different kind, viz, the funds available for research show a rather alarming tendency to accumulate in the hands of a few large observatories, leaving many astronomers who could do useful work without the means of doing it. A conspicuous example is afforded by the present state of the work for the astrographic chart initiated in Paris seventeen years ago. On the one hand, a few of the large observatories have easily acquired funds not only for taking and measuring the plates and printing the results, but for publishing an expensive set of charts which will be of very little use to anyone; on the other hand, some of their colleagues have found the utmost difficulty in getting funds for even taking the plates; others have got so far, but can not proceed to measure them; and very few, indeed, have yet funds for printing. If there had been a true spirit of cooperation for the general good in this enterprise, surely some of the funds being squandered on the comparatively useless charts would have been devoted to the proper completion of the only part of the scheme which has a chance of fulfillment. I do not mean to imply that this would have been an easy matter to arrange, but it is noteworthy that no attempt in this direction has been made, and that as a consequence a promising scheme is doomed to failure in one important particular. For though the survey of the whole sky to the eleventh magnitude may some day be completed, it will be sadly lacking in homogeneity. Some sections are finished before others are begun, so that in the vital matter of epoch we shall have a scrappy and straggling series instead of a compact whole.

Cooperation in scientific work, the necessity of which is being borne in upon us from all sides, is nevertheless beset with difficulties, and no doubt we shall only reach success through a series of failures, but we shall reach it the more rapidly if we note carefully the weaknesses of successive attempts. In the particular scheme of the astrographic chart, I think an error which should be avoided in future was made by those who have access to the chief sources of astronomical endowment. They have made the enterprise doubly difficult for their colleagues, firstly, by setting a standard of work which was unattainable with limited resources, and, secondly, by depleting the reserves which might have gone to assist the weaker observatories.

It is easier to draw attention to these modern tendencies than to suggest a remedy for them. It may, perhaps, be questioned whether a remedy is either possible or necessary; it may be urged that it is both inevitable and desirable that astronomical observation should gravitate more and more to those well-equipped observatories where it can be best conducted, and that new resources will obtain the greatest results when added to a working capital which is already large. From the purely economical point of view of getting results most rapidly, these conclusions may be true. But if we look at the human side of the question, I hope we shall dissent from them; if we think first of astronomers rather than of the accumulation of astronomical facts I hope we shall admit that something must be done to check the excessive specialization and the inequalities of opportunity, toward which there is a danger of our drifting. We can not afford the division of astronomers into two types; one isolated in a well-equipped observatory in a fine but rather inaccessible climate, spending his whole time in observing or taking photographs; another in the midst of civilization, enjoying all the advantages of intercourse with other scientific men, but with no telescope worth using, and dependent for his material on the observations made by others. Some division of labor in this way is doubtless advantageous, but we must beware lest the division become too sharply pronounced. Will it be possible to prevent its undue growth by some alternation of duties? Can the hermit observer and the university professor take turn and turn about to the common benefit? The proposal is, perhaps, a little revolutionary, and has the obvious disadvantages of inconvenience and expense at the epochs of change, but I do not think it should be set aside on these grounds.

I must admit, however, that I am not ready with a panacea. It has been chiefly my object to draw attention to some modern tendencies in astronomical work, hoping that the remedies may be evolved from a general consideration of them. Such questions of the relationship of the worker to his work are even harder to solve than those we meet with in the work itself. But there is at least this excuse for noticing them on an occasion like the present, that they are to some extent common to all departments of knowledge, and our difficulties may come to the notice of others who have had occasion to consider them in other connections and may be able to help us. Or, again, we may take the more flattering view that the human problems of astronomy to-day may be those of some other science to-morrow, for astronomy is one of the oldest of the sciences and has already passed through many stages through which others must pass. In any case, we must deal with these problems in the sight of all men, and of all the consequences entailed by our lately acquired opportunities none are more interesting and none can be more important to us than those affecting the astronomer himself.

RADIATION IN THE SOLAR SYSTEM.[a]

By Prof. J. H. Poynting, F. R. S.

I propose to discuss this afternoon certain effects of the energy which is continuously pouring out from the sun on all sides with the speed of light, the energy which we call sunlight when we enjoy the brilliance of a cloudless sky, which we call heat when we bask in its warmth, the stream of radiation which supports all life on our globe and is the source of all our energy.

As we all know, this ceaseless stream of energy is a form of wave motion. If we pass a beam of sunlight or its equivalent, the beam from an electric arc, through a prism, the disturbance is analyzed into a spectrum of colors, each color of a different wave length, the length of wave changing as we go down the spectrum from, say, one thirty-thousandth of an inch in the red to one eighty-thousandth of an inch in the blue or violet.

But this visible spectrum is merely the part of the stream of radiation which affects the eye. Beyond the violet are the still shorter waves which affect a photographic plate or a fluorescent screen, and will pass through certain substances opaque to ordinary light. Here, for instance, is a filter devised by Professor Wood which stops visible rays, but allows the shorter invisible waves to pass and excite the fluorescence of a platinocyanide screen.

Again, beyond the red end are still longer waves, which are present in very considerable amount, and can be rendered evident by their heating effect. We can easily filter out the visible rays and still leave these long waves in the beam by passing it through a thin sheet of vulcanite. A piece of phosphorus placed at the focus of these invisible rays is at once fired, or a thermometer quickly rises in temperature. The waves which have been observed and studied up to the present time range over some nine octaves, from the long waves described to the section yesterday by Professor Rubens, waves of

[a]Afternoon address delivered at the Cambridge meeting of the British Association, August 23, 1904. Reprinted from author's corrected copy.

which there are only 400 in an inch, down to the short waves found by Schumann in the radiation given off by hydrogen under the influence of the electric discharge, waves of which there are a quarter of a million in an inch. No doubt the range will be extended.

Radiant energy consists of a mixture of any or all of these wave lengths, but the eye is only sensitive at the most to a little more than one octave in the nine or more.

This radiation is emitted not only by incandescent bodies such as the sun, the electric arc, or flames. All bodies are pouring out radiant energy, however hot or cold they may be. In this room we see things by the radiation which they reflect from the daylight. But, besides this borrowed radiation, every surface in the room is sending out radiation of its own. Energy is pouring forth from walls, ceiling, floor, rushing about with the speed of light, striking against the opposite surfaces, and being reflected, scattered, and absorbed. And though this radiation does not affect our eyes, it is of the utmost importance in keeping us warm. Could it be stopped, we should soon be driven out by the intense cold, or remain to be frozen to death.

As the temperature of a body is raised, the stream of radiation it pours out increases in quantity. But it also changes in quality. Probably the surface always sends out waves of all lengths from the longest to the shortest, but at first, when it is cold, the long waves alone are appreciable. As it gets hotter, though all the waves become more intense, the shorter ones increase most in intensity, and ultimately they become so prominent that they affect our sense of sight, and then we say that the body is red or white hot.

The quality of the stream depends on the nature of the surface, some surfaces sending out more than others at the same temperature. But the stream is the greatest from a surface which is, when cold, quite black. Its blackness means that it entirely absorbs whatever radiation falls upon it, and such a surface when heated sends out radiation of every kind, and for a given temperature each kind of radiation is present to the full extent—that is, no surface sends out more of a given wave length than a black surface at a given temperature.

A very simple experiment shows that a black surface is a better radiator, or pours out more energy when hot, than a surface which does not absorb fully, but reflects much of the radiation which falls upon it. If a platinum foil with some black marks on it be heated to redness, the marks, black when cold, are much brighter than the surrounding metal when hot; they are, in fact, pouring out much more visible radiation than the metal.

It is with these black surfaces that I am concerned to-day. But, inasmuch as it seems absurd to call them black when they are white

hot, I prefer to call them full radiators, since they radiate more fully than any others.

For a long time past experiments have been made to seek a law connecting the radiation or energy flow from a black or fully radiating surface with its temperature. But it was only twenty-five years ago that a law was suggested by Stefan which agrees at all satisfactorily with experiment. This law is that the stream of energy is proportional to the fourth power of the temperature, reckoned from the absolute zero 273° below freezing point on the centigrade scale. This suggestion of Stefan served as the starting point of new and most fertile researches, both theoretical and practical, and we are glad to welcome to this meeting Professors Wien, Lummer, and Rubens, who have all done most brilliant work on the subject.

Among the researches on radiation recently carried out is one by Kurlbaum, in which he determined the actual amount of energy issuing from the black or fully radiating surface per second at 100° C., and therefore at any temperature.

Here is a table which gives the amount at various temperatures, as determined by Kurlbaum:

Rate of flow of energy from 1 cm² of fully radiating or "black" surface.

Absolute temperature.	Grams of water heated 1° per second.
	Calories.
0°	0.000000
100° air boils	0.000127
300° earth's surface	0.010300
1,000° red heat	1.270000
3,000° arc carbon	103.000000
6,000°	1,650.000000
6,250°	1,930.000000

As an illustration of the "fourth power law," let us see what value it will give us for the temperature of the sun, assuming that he is a full radiator, or that his surface, if cooled down, would be quite black.

We can measure approximately the stream of energy which the sun is pouring out by intercepting the beam falling on a surface exposed to full sunlight, measuring the heat given to that surface per second, and then calculating what fraction the beam is of the whole stream issuing from the sun.

This was first done by Pouillet, and his method will serve to illustrate the principle of all other methods.

In his apparatus the sunlight fell full upon a box containing water, and the rate at which the water rose in temperature gave the energy in the stream of solar radiation falling on the box.

Simple as the experiment appears, the determination is beset with difficulties, the chief being the estimation of the fraction of the energy intercepted by the atmosphere, and we are still unable to give a very definite value. Indeed, we can not yet say whether the outflow of energy is constant or whether it varies. In all probability, however, it does vary, and Professor Langley, who has devoted years of work to the subject, has recently obtained evidence indicating quite considerable variation.

We may, however, assume that we are not very far from the true value if we say that the stream of radiation from the sun falling perpendicularly on 1 cm² outside the earth's atmosphere will heat 1 gm. of water one twenty-fourth of a degree centigrade every second, or will give one twenty-fourth of a calory per second.

Now, the area of a sphere round the sun at the distance of the earth is 46,000 times the area of the sun's surface. The energy from 1 cm² of the sun thus passes through 46,000 cm² at the surface of the earth. It is therefore 46,000 multiplied by one twenty-fourth calories, or 1,920 calory-seconds. But from the table already given a black surface at 6,250° absolute, say 6,000° C., gives 1,930 calories per second, or the temperature of the sun's radiating surface is 6,000°, if he is a full radiator—and there is good reason to suppose that no great error is made in taking him to be one.

Let us now take another illustration of the fourth power law.

Imagine a little black body which is a good conductor of heat placed in full sunlight at the distance of the earth. Let it be 1 cm² in cross section, so that it is receiving one twenty-fourth of a calory per second.

It will soon warm up to such a temperature that it gives out just as much as it receives, and since it is so small heat will rapidly flow through it from side to side, so that it will all be very nearly at the same temperature. A sphere 1 cm² in cross section has area 4 cm², so that it must be giving out from each square centimeter of its surface $\frac{1}{96} = 0.0104$ calory each second. From the table above it will be seen that this corresponds very nearly indeed to a temperature of 300° absolute or 27° C., say 80° F.

It is to be noted that this only applies to a little round body. A flat plate facing the sun would be about 60° C. hotter, while if it were edgewise to the sun it might be very much colder.

Let us now see what would be the temperature of the small black sphere at other distances from the sun. It is easily seen that inasmuch as the heat received, and therefore that given out, varies inversely as the square of the distance, the temperature, by the fourth power law, will vary inversely as the square root of the distance.

Here is a table of temperatures of small black spheres due to solar radiation:

Distance from sun's center.	Temperature, centigrade.
3¾ million miles	1,200°, cast iron melts.
23 million miles	327°, lead nearly melts.
At Mercury's distance	210°, tin nearly melts.
At Venus's distance	80°, alcohol boils freely.
At earth's distance	27°, warm summer day.
At Mars's distance	—30°, arctic cold.
At Neptune's distance	—219°, nitrogen frozen.

We see from this table that the temperature at the earth's distance is remarkably near the average temperature of the earth's surface, which is usually estimated as about 16° C., or 60° F. This can hardly be regarded as a mere coincidence. The surface of the earth receives, we know, an amount of heat from the inside almost infinitesimal compared with that which it receives from the sun, and on the sun, therefore, we depend for our temperature. The earth acquires such a temperature, in fact, that it radiates out what it receives from the sun. The earth is far too great for the distribution of heat by conduction to play any serious part in equalizing the temperature of different regions. But the rotation about its axis secures nearly uniform temperature in a given latitude, and the movements of the atmosphere tend to equalize temperatures in different latitudes. Hence we should expect the earth to have, on the average, nearly the temperature of the small black body at the same distance, slightly less because it reflects some of the solar radiation, and we find that it is, in fact, some 10° C. less.

Professor Wien was the first to point out that the temperature of the earth has nearly the value which we should expect from the fourth power law.

Here is a table showing the average temperatures of the surfaces of the first four planets on the supposition that they are earth-like in all their conditions:

Table of temperatures of earth-like planets.

	° C.
Mercury	194
Venus	69
Earth	17
Mars	—38

The most interesting case is that of Mars. He has, we know, a day nearly the same in length as ours. His axis is inclined to the ecliptic only a little more than ours, and he has some kind of atmosphere. It is exceedingly difficult to suppose, then, that his average temperature can differ much from —38° C. His atmosphere may be less protective, so that his day temperature may be higher, but then, to compensate, his night temperature will be lower. Even his highest equa-

torial temperature can not be much higher than the average. On certain suppositions I find that it is still 20° below the freezing point, and until some new conditions can be pointed out which enable him to establish far higher temperatures than the earth would have at the same distance it is hard to believe that he can have polar caps of frozen water melting to liquid in his summer and filling rivers or canals. Unless he is very different from the earth, his whole surface is below the freezing point.

Let us now turn from these temperature effects of radiation to another class of effects, those due to pressure.

More than thirty years ago Clerk Maxwell showed that on his electromagnetic theory of light, light and all radiation like light should press against any surface on which it falls. There should also be a pressure back against any surface from which radiation is reflected or from which it is issuing as a source, the value in every case being equal to the energy in a cubic centimeter of the stream. The existence of this pressure was fully demonstrated independently by Lebedew and by Nichols and Hull some years ago in brilliant experiments in which they allowed a beam of light to fall on a suspended disk in a vacuum. The disk was repelled, and they measured the repulsion and found it to be about that required by Maxwell's theory. Nichols and Hull have since repeated the experiment with greater exactness, and there is now no doubt that the pressure exists and that it has Maxwell's value.

The radiation, then, poured out by the sun is not only a stream of energy, but it is also, as it were, a stream of pressure pressing out the heavenly bodies on which it falls. Since the stream thins out as it diverges, according to the inverse square of the distance, the pressure on a given surface falls off according to the same law. We know the energy in a cubic centimeter of sunlight at the distance of the earth, since, moving with the velocity of light, it will supply one twenty-fourth of a calory per second. It is easy to calculate that it will press with a force of 6 by 10^{5} degree on a square centimeter, an amount so small that on the whole earth it is but 75,000 tons, a mere trifle compared with the 3,000,000 billion tons with which the sun pulls the earth by his gravitation.

But now notice the remarkable effect of size on the relation between the radiation pressure and the gravitative pull. One is on the surface and proportional to the surface, while the other penetrates the surface and pulls every grain of matter throughout the whole volume.

Suppose we could divide the earth up into eight equal globes. Each would have half the diameter of the earth and a quarter the surface. The eight would expose twice the surface which the earth exposes, and the total radiation pressure would be doubled, while the total gravitative pull would be the same as before. Now divide up each of the

eight into eight more equal globes. Again the radiation pressure would be doubled, while gravitation would be the same.

Continue the process, and it is evident that by successive division we should at last arrive at globes so small and with total surfaces so great that the pressure of the radiation would balance the pull of gravitation. Mere arithmetic shows that this balance would occur when the earth was divided up into little spheres each one forty-thousandth of a centimeter in diameter.

In other words, a little speck one forty-thousandth of a centimeter, say one one-hundred-thousandth of an inch in diameter, and of density equal to that of the earth, would be neither attracted nor repelled by the sun.

This balance would hold at all distances, since both would vary in the same way with the distance. Our arithmetic comes to this, that if the earth were spread out in a thin spherical shell with radius about four times the distance of Neptune, the repulsion of sunlight falling on it would balance the inward pull by the sun and it would have no tendency to contract.

With further division repulsion would exceed attraction, and the particles would be driven away. But I must here say that the law of repulsion does not hold down to such fine division. The repulsion is somewhat less than we have calculated, owing to the diffraction of the light.

Some very suggestive speculations with regard to comets' tails have arisen from these considerations, and to these Professor Boys directed the attention of section A last year. We may imagine that the nucleus of a comet consists of small meteorites. When these come near the sun they are heated and explosions occur, and fine dust is produced not previously present. If the dust is sufficiently fine, radiation may overpower gravitation and drive it away from the sun, and we may have a manifestation of this expelled dust in the tail of the comet.

I do not, however, want to dwell on this to-day, but to look at the subject in another way.

Let us again introduce our small black sphere, and let us make it 1 cm.^{2} in cross section, 1.13 cm. in diameter, and of the density of the earth. The gravitation pull on it is forty-two thousand times the radiation pressure.

Now let us see the effect of size on the radiating body. Let us halve the diameter of the sun. He would then have one-eighth the mass and one-quarter the surface. Or, while his pull was reduced to one-eighth, his radiation push would only be reduced to one-quarter. The pull would now be only twenty-one thousand times the push. Halve the diameter again, and the pull would be only ten thousand five hundred times the push. Reduce the diam-

eter to one forty-two-thousandth of its orignal value, that is, to about 20 miles, and the pull would equal the push.

In other words, a sun as hot as ours and 20 miles in diameter would repel bodies less than 1 cm. in diameter, and could only hold in those which were larger.

But it is, of course, absurd to think of such a small sun as this having so high a temperature as 6,000°. Let us then reduce the temperature to one-twentieth, say 306° absolute, or the temperature of the earth. Then the radiation would be reduced to the fourth power of one-twentieth, or one one-hundred-and-sixty-thousandth, and the diameter would have to be reduced to one one-hundred-and-sixty-thousandth of 20 miles, or about 20 cm., say 8 inches, when again radiation would balance gravitation.

It is not very difficult to show that if we had two equal spheres each of the density and temperature of the earth they would neither attract nor repel each other—their radiation pressure would balance the gravitative pull—when their diameters were about 2.26 cm., when, in fact, they were about the size of large marbles.

It must be remembered that this is only true for spheres out in space receiving no appreciable radiation from the surrounding region.

It would appear that we have arrived at a result of some importance in considering the aggregation of small meteorites. Imagine a thinly scattered stream of small meteorites at the distance of the earth from the sun. Then, even if they be as large as marbles, they may have no tendency to move together. If they are smaller they may even tend to move apart and scatter.

In conclusion, let me mention one more effect of this radiation pressure. You will remember that radiation presses back against any surface from which it issues. If, then, a sphere at rest in space is radiating equally on all sides it is pressed equally on all sides, and the net result is a balance between the pressures. But suppose that it is moving. It is following up the energy which it pours forth in front, crowding it into a smaller space than if it were at rest, making it more dense. Hence the pressure is slightly greater, and it can be shown that it is greater the greater the velocity and the higher the temperature. On the other hand, it is drawing away from the energy which it pours out behind, thinning it out, as it were, and the pressure at the back is slightly less than if the sphere were at rest.

The net result is a force opposing the motion, a force like a viscous friction, always tending to reduce the speed.

Thus calculation shows that there is a retarding force on the earth as it moves along its orbit amounting in all to about 2,500 kgm. Not very serious, for in billions of years it will only reduce the velocity by one in a million, and it will only have serious effects if the life of

the earth is prolonged at its present temperature to hundreds of billions of years.

But here again size is everything. Reduce the diameter of the moving body, and the retarding effect increases in proportion to the reduction. If the earth were reduced to the size of a marble, the effect would be appreciable in a hundred thousand years. If it were reduced to a speck of dust a thousandth of a centimeter in diameter, the effect would be appreciable in a hundred years.

Note what the effect would be. Imagine a dust particle shot out from the earth and left behind to circulate on its own account round the sun. It would be heated by the sun and would be radiating out on all sides. As it journeyed forward there would be a resisting force tending to stop it. But instead of acting in this way the resistance would enable the sun to pull the particle inward, and the fall inward would actually increase the velocity. This increase in the velocity would increase the resistance, and at the same time the approach to the sun would raise its temperature, increase the radiation, and so increase the resistance still further. The particle would therefore move in a mcre and more rapid orbit, and ultimately it would fall into the sun. Small marble-sized meteorites would fall in from the distance of the earth probably in a few million years. Small particles of dust would be swept in in a few thousand years.

Thus the sun is ever at work keeping the space round him free from dust. If the particles are very minute he drives them forth into outer space. If they are larger he draws them in. It is just possible that we have evidence of this drawing in in the zodiacal light, that vast dust-like ring which stretches from the sun outwards far beyond the orbit of the earth and is at once the largest and the most mysterious member of the solar system.

CONDENSATION NUCLEI.[a]

By C. T. R. Wilson, F. R. S.,
Fellow of Sidney Sussex College, Cambridge, England.

If we take the ordinary air of a room and inclose it in a glass vessel containing some water and provided with some means of increasing or diminishing the volume at will, we are able to observe the following phenomena: If the air has been allowed to stand sufficiently long to become saturated with water vapor, any increase of volume, even if very slight, causes the formation of a fog throughout the volume of the moist air. This is easily made visible by concentrating a powerful beam of light on the contents of the vessel; or, by placing a small source of light behind the vessel, brilliant-colored rings or coronas may be seen surrounding the source. If the air be made to contract again to its original volume, a second expansion like the first will again give a similar fog, but when this process has been several times repeated the fogs become thinner, the drops being fewer and larger; we get at length a fine rain on expansion rather than a fog, the drops falling to the bottom of the vessel within a few seconds instead of remaining in suspension for many minutes like the first-formed fog particles. When this stage has been reached, the next and all succeeding expansions produce no drops at all, no condensation resulting elsewhere than on the walls of the vessel. If ordinary air be now admitted into the vessel, drops will again be seen on expansion, unless the air introduced has entered through a tightly pressed plug of cotton wool, or has been otherwise filtered, in which case no drops are seen.

The phenomena are readily explained if we suppose that water can not under ordinary circumstances condense in the form of drops unless suitable nuclei are present to serve as starting points for the drops. These nuclei are present in very varying numbers in ordinary atmospheric air, from which they may be removed by filtering, or

[a] A paper presented at the International Electrical Congress of St. Louis, 1904. Reprinted from author's revised copy.

by repeatedly forming a cloud by expansion, and allowing the drops to fall to the bottom of the vessel. Both the facts and the explanation have been long known. The particles which serve as the nuclei of the drops formed, when ordinary atmospheric air is allowed to expand slightly, are conveniently called "dust" particles; they are generally too small to be themselves visible, and it would be difficult to find a means of determining whether they consist of solid particles or of minute drops of liquid. The number of these dust particles per cubic centimeter of air in different localities and under different weather conditions has been investigated by Aitken and by others with the aid of the ingenious dust-counting apparatus invented by him.

It is not difficult to understand why nuclei should be necessary for the condensation of water in the form of drops. Lord Kelvin proved that the pressure of aqueous vapor necessary for equilibrium over a convex or concave surface of water differed from that over a flat surface, being less over a concave and greater over a convex surface. He shows how we may calculate the difference. A very small drop of pure water will, if we assume the surface tension to remain the same for very small drops as for large ones, evaporate even when surrounded by vapor many times more dense than that in equilibrium at the same temperature over a flat surface. Thus unless the initial stages of the growth of the drops can be, as it were, omitted, owing to the presence of not too minute nuclei, a high degree of supersaturation may exist without any condensation in the form of rain or cloud resulting. Lord Kelvin showed that to alter the equilibrium vapor pressure by one part in a thousand the radius of curvature of a spherical drop must amount to about 10^{-4} cm. Thus very minute nuclei will enable a cloud to be formed with a very slight degree of supersaturation; in other words, as a result of a very slight expansion of the air if this has been initially saturated with water vapor.

Lord Kelvin refrained from extending his calculations to curvatures of greater amount, as the surface tension can not remain independent of the radius much beyond that limit. It is convenient, however, to extend the calculations to greater curvatures; for although the results obtained can not be considered as quantitatively correct, they enable us to form a picture of the mode of action of nuclei of different kinds. Let us imagine an arrangement equivalent to that considered by Lord Kelvin; but since we are only here concerned with convex surfaces, let the capillary tube be joined as a side tube to the lower part of a tall vessel of water. The capillary must be supposed to have walls of such a nature as not to be wetted by water, and let us suppose the open end of it to be bent round, so that it points vertically upward, and that the height of the vertical portion can be adjusted to bring the meniscus to the open end of the tube.

Let the whole apparatus be contained in a closed vessel containing only water vapor.

We have then the convex water-air meniscus depressed below the level of the flat surface in the large vessel to a depth h, such that $gwh = 2\mathrm{T}/r$, where g is the acceleration due to gravity, w the density of the liquid ($w = 1$ in the present case), T is the surface tension, and r the radius of curvature. Thus the pressure of the vapor in contact with the meniscus must be greater than that over the flat surface by that due to the weight of a column of water vapor of height h, the pressure at the top of the column being that required for equilibrium over a flat surface at the given temperature. This increased pressure must, moreover, be the pressure necessary for equilibrium over the curved surface; distillation from the one surface to the other would otherwise take place, resulting in a continuous circulation. To find this pressure p_2, p_1 being that at the flat surface we have $dp = g\rho dh$,

$$h = \frac{1}{g}\int\frac{dp}{\rho}$$

ρ being the density of the steam. If we assume Boyle's law to be obeyed, this gives

$$h = \frac{\mathrm{R}t}{g}\log_e\frac{p_2}{p_1} = \frac{\mathrm{R}t}{g}\log_e\frac{\rho_2}{\rho_1}$$

R being the constant in the equation $pv = \mathrm{R}t$, t being the absolute temperature, ρ_1, ρ_2 the density of the vapor at the two surfaces respectively.

But $h = 2\mathrm{T}/rg$, thus

$$\log_e\frac{p_2}{p_1} = \log_e\frac{\rho_2}{\rho_1} = \frac{1}{\mathrm{R}t}\cdot\frac{2\mathrm{T}}{r}$$

We have thus the means of calculating the pressure, or the density, which water vapor must have in order that it may be in equilibrium in contact with a drop of any size. The equilibrium is obviously unstable; a drop, if too big for equilibrium, will grow so long as the supersaturated condition is maintained; if too small it will evaporate completely. The possession of a charge of electricity by the drop or the existence of a dissolved substance within it will cause the drop to be stable if its size be less than a certain limit, depending on the magnitude of the charge or the quantity of dissolved substance. Let us consider the case of electrification. We may imagine the water surface in one limb of a U tube in an arrangement like that described above, to be uniformly charged with electricity by holding a very short distance above it a parallel conducting surface maintained at a different potential. It is immaterial whether the water surface be flat or curved; a tension of $2\pi\sigma^2$ dynes per square centimeter will be exerted on the end of the column, σ being the charge per square centimeter. This will raise the electrified surface above the level which it

would have occupied in the absence of the charge through a distance $2\pi\sigma^2/g$, and there will be a corresponding diminution in the saturation vapor pressure. The vapor pressure necessary for equilibrium over a charged drop is now given by the equation

$$\log_e \frac{p_2}{p_1} = \frac{1}{Rt}\left(\frac{2T}{r} - 2\pi\sigma^2\right) = \frac{1}{Rt}\left(\frac{2T}{r} - \frac{e^2}{8\pi r^4}\right)$$

where p_1 is the saturation vapor pressure over a flat, uncharged surface, p_2 that necessary for equilibrium at the same temperature in presence of the drops, and e is the charge on each drop. In an atmosphere saturated with respect to a flat uncharged surface a drop carrying a charge e would be in stable equilibrium if its radius were such that the two terms on the right-hand side of the above equation were equal, i. e., when $r^3 = e^2/16\pi T$. If the density of the vapor were increased the drop would become larger, the equilibrium remaining stable until the vapor pressure reached the maximum value corresponding to the above equation. To find this we have on differentiating

$$\frac{1}{p}\frac{dp}{dr} = \frac{1}{Rt}\left(-\frac{2T}{r^2} + \frac{1}{2}\frac{e^2}{\pi r^5}\right)$$

The maximum vapor pressure in contact with the drops occurs when $r^3 = e^2/4\pi T$, and has the value given by

$$\log \frac{p_2}{p_1} = \frac{3T}{2\,Rtr}$$

If the pressure of the vapor be increased beyond this limit the unstable condition is reached, and the drop increases in size so long as the supply of vapor is unlimited. In most cases the final size of the drops would be determined by the amount of vapor initially present, and the number of drops among which the water is distributed; unless they are very numerous, and, therefore, very small when full grown, they will grow until the vapor is not sensibly supersaturated; it will only be in very rare cases that the final size of the drops is so small that equilibrium will be reached while the vapor is at all considerably supersaturated.

It is easily seen that the behavior of drops containing dissolved substances will be quite similar. If we start with very small drops, there is for a given size of drops a certain vapor pressure corresponding to equilibrium; if we increase the density of the vapor the drop grows, the equilibrium remaining stable, until a certain size is reached, after which the drops suddenly grow to their full size. The theory of condensation on ions or other nuclei has been treated by J. J. Thomson [a] and by Langevin and Bloch.[b]

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[a] J. J. Thomson, Conduction of Electricity through Gases, p. 149.

[b] Bloch, Recherches sur la conductibilité électrique de l'air produite par le phosphore et sur les gaz récemment préparés (Paris, 1904).

LIMITING SUPERSATURATION IN DUST-FREE GASES.

When air saturated with water vapor has been freed from dust particles no drops are formed on expansion, provided that a certain critical degree of supersaturation has not been exceeded. To produce the supersaturation necessary for condensation in the form of drops in dust-free air the air must be allowed to expand suddenly, till the final volume is 1.25 times the initial volume. The condensation is rainlike in form, and the number of drops remains small although the expansion considerably exceeds this lower limit. Expansions exceeding a second limit, $v_2/v_1=1.38$ give fogs, which increase rapidly in density, i. e., in the number of the drops as the expansion is increased beyond this limit. In such experiments it is of course necessary that the apparatus used should be such that a very rapid change of volume can be brought about, and that the ratio of the final to the initial volume is known with certainty. Some years ago I introduced a method which has proved suitable for the purpose. When this method is used it would appear from the consistency of the results obtained with cloud chambers varying in capacity from 15 to 1,500 cc. that the expansion is adiabatic and is completed before any appreciable quantity of water has had time to separate out. From the ratio of the final to the initial volume, knowing the initial temperature, we can deduce the temperature at the moment when the expansion was completed from the equation for the cooling of a gas by adiabatic expansion.

$$\frac{\theta_2}{\theta_1}=\left(\frac{v_1}{v_2}\right)^{\gamma-1}$$

γ may be taken as not differing sensibly from its value for the dry gas. Knowing the final temperature we have the data from which we can obtain the density of the vapor which would be required for saturation at the moment of completion of the expansion, and we know the actual density at that moment from the initial temperature and the ratio of the final to the initial volume. Thus the supersaturation measured by the ratio of the actual density of the vapor at the instant when the expansion is completed to the density of the saturated vapor at the temperature which the supersaturated gas then possesses can be calculated.

The supersaturation required for the rainlike condensation is found in this way to be approximately fourfold, that required for the cloudlike condensation being nearly eightfold. There are these two classes of nuclei always present in moist dust-free air, and always being produced, for however often the process of condensing water on the nuclei and allowing the drops to settle is repeated the number of drops formed in subsequent expansions is undiminished. The nuclei

which give rise to the rainlike condensation and which are at any moment present in quite small numbers are, as we shall see, ions continually being produced in the gas. They can be removed by an electric field. The cloudlike condensation occurring with large expansions is entirely unaffected by an electric field; it is independent also of the nature of the gas. If we calculate how large a drop of water would require to be in order that it should just be able to grow in vapor of eightfold supersaturation, we obtain the very small value 6.4 by 10^{-8} cm. for the radius of such drops. Thus drops not large in comparison with molecular dimensions might be expected to grow into visible drops in an atmosphere supersaturated to this extent.

THE IONS AS CONDENSATION NUCLEI.

. If we expose the cloud chamber of an expansion apparatus to the action of Roentgen rays, the air having been previously freed from dust, just the same expansion is required as in the absence of the rays to produce drops, but now we get comparatively dense fogs in place of the rainlike condensation. The cloudlike condensation obtained with expansions exceeding the second limit is not sensibly affected. Thus, when X rays pass through moist air they produce nuclei of exactly the same efficiency in promoting condensation as those which are always being produced in small numbers and to which the rainlike condensation is due. The conducting power imparted to air by the action of X rays being explained as due to the setting free of ions in the gas, it was natural to identify the nuclei with the ions.

This view was verified by studying the action of an electric field on the nuclei produced by X rays. Between two parallel plates, which formed the top and bottom of the cloud chamber of an expansion apparatus, a difference of potential of some hundred volts could be applied. With the electric field acting, the number of drops produced on expansion in air exposed to the rays was exceedingly small in comparison with the number seen in the absence of the field. The nuclei carry a charge of electricity, and are driven by the electric field against the plates immediately after being set free. The direct proof that the few nuclei, which are always present and give rise to the rainlike condensation, are also ions has been more difficult to carry out. Attempts made with small apparatus led to negative results, the number of drops being inconveniently small whether the field was applied or not. Recent experiments on a large scale, however, showed in a striking way the removal of these nuclei by the electric field. The subject has been further cleared up by the independent proof by purely electrical measurements that the air in a closed vessel is continually being ionized.

Air ionized by any of the various types of Becquerel rays or containing ions from a zinc plate exposed to weak ultra-violet light behaves on expansion like air exposed to X rays, fogs being produced in air initially saturated if the lower expansion limit $v_2/v_1=1.25$ be exceeded. The action of an electric field in removing the nuclei is the same in air ionized by Becquerel rays as in air ionized by X rays. The ions produced by the discharge from a point are similar in their action, but there is here a tendency, due probably to the products of chemical combinations brought about by the luminous discharge, for the nuclei to grow or for larger uncharged nuclei to be formed, so that a much smaller degree of supersaturation may be required to produce a cloud. The ions produced by these various methods are also identical in the velocity with which they move through air under a given potential gradient. The degree of supersaturation required to make water condense on the ions is independent of the gas.

If we make use of the equation which has been given above, connecting the maximum supersaturation with the charge of the drop, we obtain the result $e=6\times10^{-10}$ electrostatic units for a fourfold supersaturation. To obtain this number, we have, of course, extended to drops of almost molecular smallness, $r=7\times10^{-8}$ cm., an equation which could only be used with confidence when the radius was at least a thousand times as great. It is therefore somewhat remarkable that the value obtained approximates fairly closely to the values found by J. J. Thomson and by H. A. Wilson for the ionic charge. The action of the ions as condensation nuclei is not, however, completely explained, for our formula would make efficiency of the electrification in helping condensation independent of the sign of the charge. Now, the negative ions are found to require a less degree of supersaturation to make water form visible drops upon them than do the positive.

DIFFERENCE BETWEEN POSITIVE AND NEGATIVE IONS.

To study this question we may use an expansion apparatus provided with a cloud chamber, in which the air under examination is contained between two horizontal plates kept at slightly different potentials. A thin stratum of the air immediately over the lower plate is exposed to the action of X rays. A series of observations are then made, in which the rays are cut off at a definite interval of time before the expansion is made, the interval being such that all the downward-moving ions have had time to reach the lower plate while only a small proportion of the upward-moving ones have reached the much more distant upper plate before the expansion takes place. Thus at the moment of expansion we will have prac-

tically ions of only one kind present, those, namely, which are moving toward the upper plate.

In this way it has been found that in order that water may condense upon them to form visible drops the negative ions require an expansion $v_2/v_1 = 1.25$, the positive an expansion 1.31, the corresponding supersaturations being fourfold and sixfold, respectively. When ions of both kinds are present in approximately equal numbers, it is often possible to observe a difference in the density of the resulting cloud according as the expansion is below or above the limit corresponding to the degree of supersaturation necessary for the condensation of the positive ions. The increase in density was first described by J. J. Thomson, and it was suggested by him that it might be due to a difference between the positive and negative ions in their efficiency as condensation nuclei; he pointed out that such a difference, if established, would have important bearings on the subject of atmospheric electricity. For an electrical field might be expected to result in ionized air if such a degree of supersaturation was reached that condensation took place on ions of one kind only, these loaded ions being then carried down by gravity. That the drops produced under these conditions are actually negatively charged, as was to be expected from the greater efficiency of the negative ion as a nucleus, was proved by H. A. Wilson, by observing the movement of the drops in a strong electric field applied after their formation by expansion.

CHARGE CARRIED BY THE IONS.

The most important use which has been made of the fact that ions act as nuclei for the condensation of water vapor has been in the determination of the quantity of electricity carried by each ion. Two entirely different methods have been employed, both requiring the use of the expansion apparatus. In the first, that of J. J. Thomson, a measurement of the leakage of electricity through the air of the cloud chamber allows n, e, the product of the number of ions and the ionic charge, to be measured; n, the number of the ions is given by the number of the drops. The number has been obtained, not by direct counting, but from a knowledge of the quantity of water condensed, and the size of the drops as obtained from their rate of fall. The second method (used by H. A. Wilson) in its simplest form reduces itself to a determination of the strength of the electric field necessary to maintain in suspension the drops condensed upon the ions. We then have $F\,e$, the product of the strength of the field and the charge on the drop, equal to its weight. The size of the drops, and hence their weight, is again deduced from the rate of fall in the absence of the field.

OTHER PROPERTIES OF THE IONS.

There is no room for doubt that the nuclei produced by X rays and similar agents, and requiring a fourfold or sixfold supersaturation to make water condense on them, are negatively or positively charged ions. We know by other methods of studying them a great deal about the properties of ions, their velocity in an electric field, their diffusion constants and rates of recombination under different conditions. Their behavior when studied by condensation has been entirely in agreement with the results obtained by other methods; for example, the rapidity with which their number diminishes after the source of ionization has been cut off.

NUCLEI SIMILAR IN EFFICIENCY TO THE IONS, BUT NOT REMOVABLE BY AN ELECTRICAL FIELD.

Moist air exposed to weak ultraviolet light is found to contain a plentiful supply of nuclei, which require a degree of supersaturation approximately the same as do the ions, in order that a cloud may form upon them. Yet even very strong electric fields appear to be without effect in reducing the number of drops formed on expansion. Certain metals also produce in the air in contact with them similar nuclei, the clouds in this case, however, not generally attaining any considerable density, unless the expansion is great enough to cause condensation on positive ions. It is possible that we have in both these cases ions produced as a result of the expansion, there being, therefore, no time for the ions to be removed by the field before the cloud is formed.

NUCLEI MORE EFFECTIVE IN PROMOTING CONDENSATION THAN THE IONS PRODUCED BY X RAYS.

If we expose moist air to ultraviolet of moderate intensity, the result is not so simple as when the intensity is very small. Nuclei are produced which appear to grow under the action of the light, the expansion required to produce a cloud becoming less than that required by the negative ions, and becoming less and less the stronger the light and the longer the exposure. For a given intensity of the light, there appears to be a maximum size beyond which the nuclei cease to grow. A very moderate intensity is sufficient to produce nuclei which grow till the slightest expansion will form a cloud, and the growth is very rapid, so that the earlier stages are difficult to follow. With very intense ultraviolet light, the growth continues till the nuclei become visible in suitable illumination, and we get a cloud without expansion, even in unsaturated air. There can be little doubt that the growth of these nuclei into visible drops is to be attributed to the formation of some substance in solution within them. Vincent

has recently studied these visible nuclei and found some of the particles to be positively, some negatively charged, and others neutral; but he finds the evidence to be in favor of the view that the charges are, as it were, accidental, being simply due to ions which have come in contact with them. Lenard had previously shown the ionization of the air by these rays.

The very small nuclei—i. e., those which require large expansions to make drops form upon them—diffuse rapidly to the sides of the vessel, so that a fog is not formed if the radiation be cut off even one minute before the expansion is made. The nuclei which are large enough to be visible may persist for hours on account of their very slow diffusion.

Other nuclei which, like those produced by ultraviolet light, vary in size with varying conditions are those produced by heating a wire, studied some time ago by Aitken and recently by Owen. The latter has shown that the lower the temperature at which they have been given off by the wire the greater is the expansion required to catch them. They can be detected when the wire has been raised to a temperature of less than 150° C. in air. The nuclei produced by the slow oxidation of phosphorus, like those formed by the action of strong ultraviolet light, form visible clouds in air which is not supersaturated. These clouds have been studied by Barus and others. As in the cases just considered, the production of the nuclei is associated with the acquisition of conducting power by the gas. There has been a considerable amount of controversy as to the nature of the conduction of electricity in air which has passed over phosphorus. The experiments of Bloch [a] have, however, proved, from the nature of the curve obtained for the relation between current and potential difference, that we have here a true case of ionization. His measurements of the velocity of the ions showed that they have a very small mobility as compared with the ions due to X rays. His experiments leave little room for doubt that these slow-moving ions are identical with the nuclei. The mobility is about a thousand times as small as that of the ions formed by X rays.

Certain experiments of Harms,[b] and of Elster and Geitel,[c] appear to show that by the oxidation of phosphorus free ions are produced in addition to the visible cloud particles. These we should expect to be rapidly removed by diffusion and recombination, and, after passing through any considerable length of tubing, we should expect only the loaded ions to persist. The absence of unloaded ions in Bloch's experiments is perhaps to be explained in this way.

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[a] Bloch, loc. cit.

[b] Harms, Phys. Zeit., 1st May, 1903.

[c] Elster and Geitel, Phys. Zeit., 15th May, 1903.

The nuclei found in freshly prepared gases, and studied especially by Townsend, resemble in many ways those resulting from the oxidation of phosphorus. Like them, they form clouds without supersaturation, and they carry a charge of electricity. In some cases, at least, as was shown by Townsend's experiments, the charge on each nucleus is the ionic charge. Bloch has studied the mobility of these ions, and in agreement with Townsend has found it to be of the same order as that of the phosphorus ions.

By the splashing of water or aqueous solutions, or the bubbling of air through water or solutions, nuclei are produced requiring only a slight expansion in order that water may condense upon them. These nuclei have lately been studied by Barus. He finds that the nuclei produced from salt solutions are much more persistent than those arising from distilled water. It is most natural to regard these nuclei, as does Barus,[a] as small drops which have evaporated till the strength of the solution is such that the effect of the dissolved substance on the vapor pressure counterbalances that of the surface tension. The splashing or bubbling process also imparts temporary conducting power to the gas. According to Kaehler, with pure distilled water the conduction is practically unipolar and due to the presence of negative ions having a mobility equal to that of the ions produced by X rays. With salt water positive ions of very small mobility are produced in addition.

In the products of combustion from flames we find again ions of small mobility, and no appreciable degree of supersaturation is required to produce a cloud.

As Bloch points out, there are apparently two classes of ions. We have, first, ions like those produced by X rays and similar agents, which have a definite velocity in an electric field of given strength and require a definite degree of supersaturation—fourfold or sixfold, according to the sign of the charge—in order that water may condense upon them.

The second class consists of ions of variable mobility, about one-thousandth part of that of the ions of the first class, and they have the power of condensing water to form visible drops without supersaturation. Ions with intermediate properties are rarely, if ever, met with. Bloch points out that we should expect an important difference between the two classes with respect to the result of recombination of positive and negative ions. In the first class the nucleus owes its existence to the charge; if two oppositely charged ions (which we may regard as minute charged drops) combine, we should expect the resultant uncharged nucleus to evaporate at once. On the other hand, the persistence of the ions of the second class can not be due to the charge alone, and neutralization of the charge will not result in

[a] Barus, The Structure of the Nucleus.

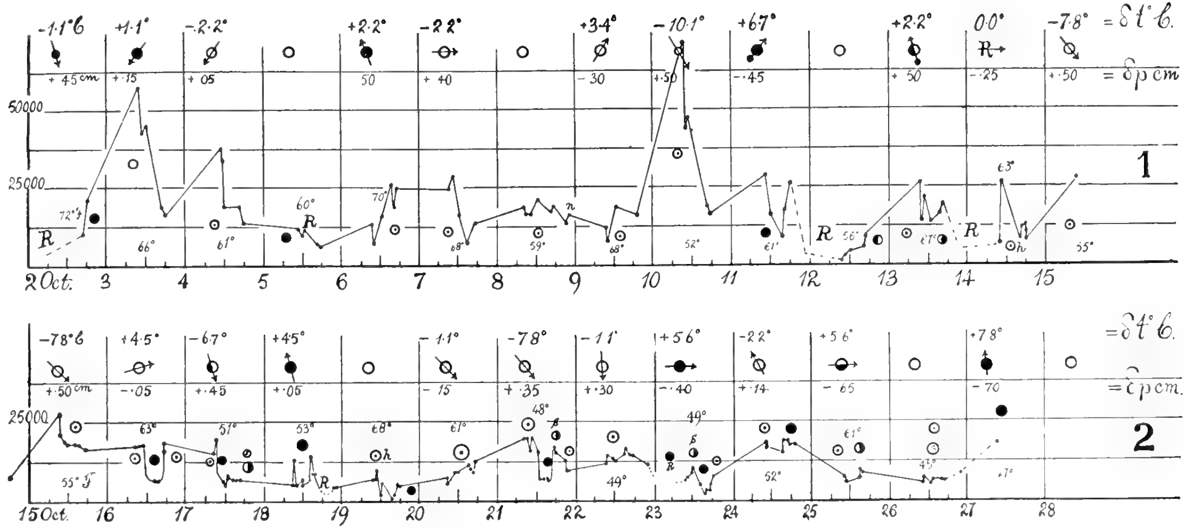
evaporation of the nucleus. From recombination of these ions persistent uncharged nuclei will result. The facts are found to be in complete accord with these considerations.

If we produce a cloud in dust-free air by an expansion exceeding 1.25 after exposure to X rays, or exceeding 1.38 in the absence of ionizing agents, the drops formed, if made to evaporate by compression, appear to leave behind nuclei requiring only slight expansion to make water condense on them. J. J. Thomson has pointed out that there may be a certain size for which even uncharged drops of pure water may be stable in an unsaturated atmosphere. For, according to the experiments of Reinold and Rücker, the surface tension of thin films has a minimum for a certain thickness. There may, therefore, be a certain size (somewhat smaller than that corresponding to minimum surface tension) for which the potential energy of a drop due to surface tension has a minimum value. Such a drop would be in equilibrium in vapor saturated with respect to a flat surface.

Bloch, following Langevin, works out, in the paper already referred to, the theory of condensation of water vapor on ions. He shows that we might expect drops of about 10 $\mu\mu$ in diameter to be stable, on account of the variation in surface tension in that region, but we should not expect to meet with drops of which the diameter was comprised between that limit and a very low value, the equilibrium of such particles being unstable. The behavior of other substances than water would probably be similar. In this way Bloch explains the fact that we do not meet with ions of mobility intermediate between about 1 centimeter and one three-hundredths centimeter per second for a field of 1 volt per centimeter.

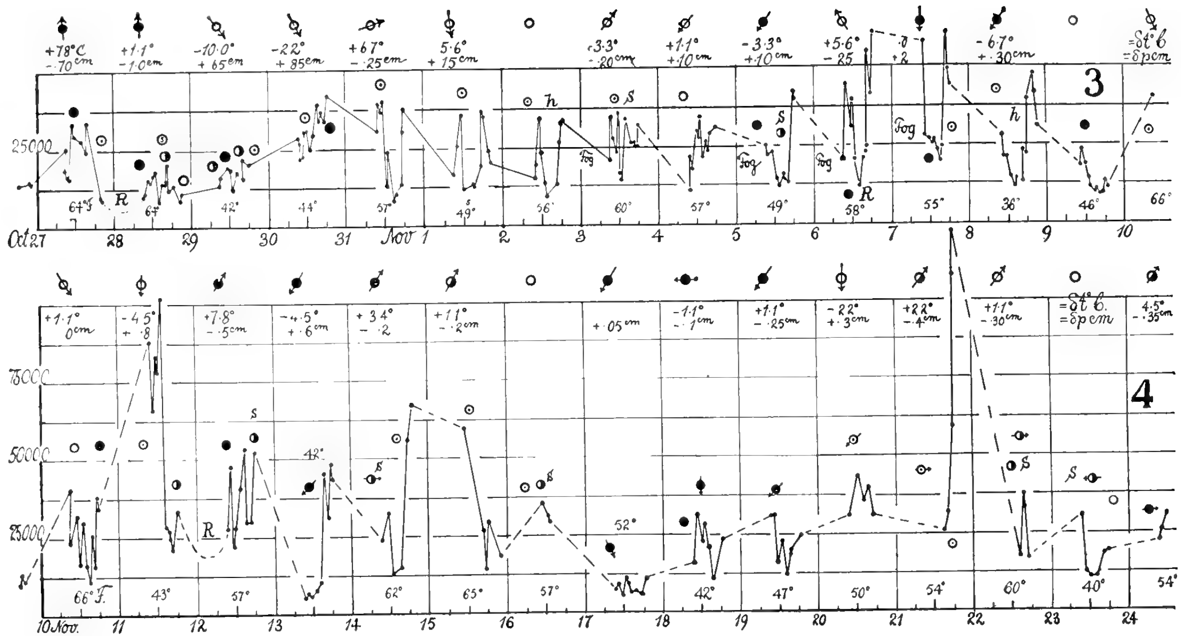
There are then three principal classes of nuclei: (1) The ions proper, requiring a fourfold or sixfold supersaturation to cause water to condense on them, and having a mobility exceeding 1 centimeter per second in a field of 1 volt per centimeter; (2) loaded ions requiring little or no supersaturation to make water condense on them, and having a mobility generally less than a thousandth part of that of the ions proper; (3) uncharged nuclei, resembling the second class in requiring little or no supersaturation in order that visible drops may form upon them.

[The accompanying illustrations—most of them from an article on "Nucleation during cold weather," by Dr. Carl Barus, which appeared in the Physical Review for April, 1903—are here appended to show in a graphic manner the number of nuclei in atmospheric air. Doctor Barus, who prepared these charts, has for several years been conducting investigations on this subject, under the auspices of the Smithsonian Institution, which has published several of his memoirs.—Editor.]



CHARTS 1, 2.—NUMBER OF NUCLEI PER CUBIC CENTIMETER OF ATMOSPHERIC AIR, OR NUCLEATION (ORDINATES) FROM OCTOBER 2 TO 28.

Increments of pressure (centimeters of mercury), temperature (degrees Centigrade), and winds given above the curves from United States Weather Bureau (Block Island) observations. Local weather data (temperatures in degrees Fahrenheit, at about noon) nearer the curve. Observations from October 2 to 15 without water bath. All data inserted in chart at about the time of observation. Lower curves, corresponding thermograph temperatures.



CHARTS 3, 4.—NUCLEATION, OCTOBER 27 TO NOVEMBER 24.

Tall cylindrical receiver (50 cm. long, 13 cm. diameter). Winds, temperature, and pressure increments above curves, from United States Weather Bureau. Local data nearer the curve. Places of data here and elsewhere correspond to the time of observation.

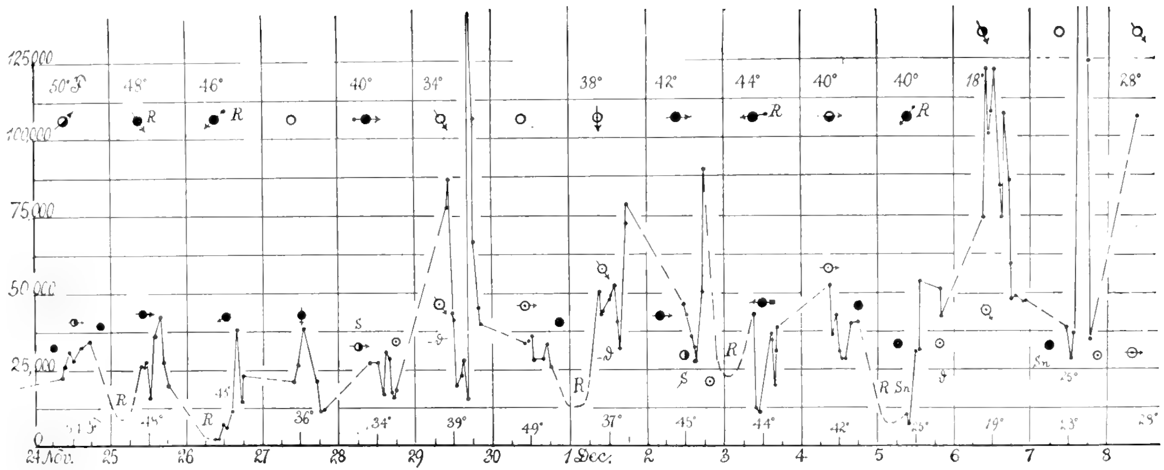


CHART 5.—NUCLEATION, NOVEMBER 24 TO DECEMBER 8.

Temperature (degrees Fahrenheit) and winds from United States Weather Bureau, above curve. Local data nearer the curve.

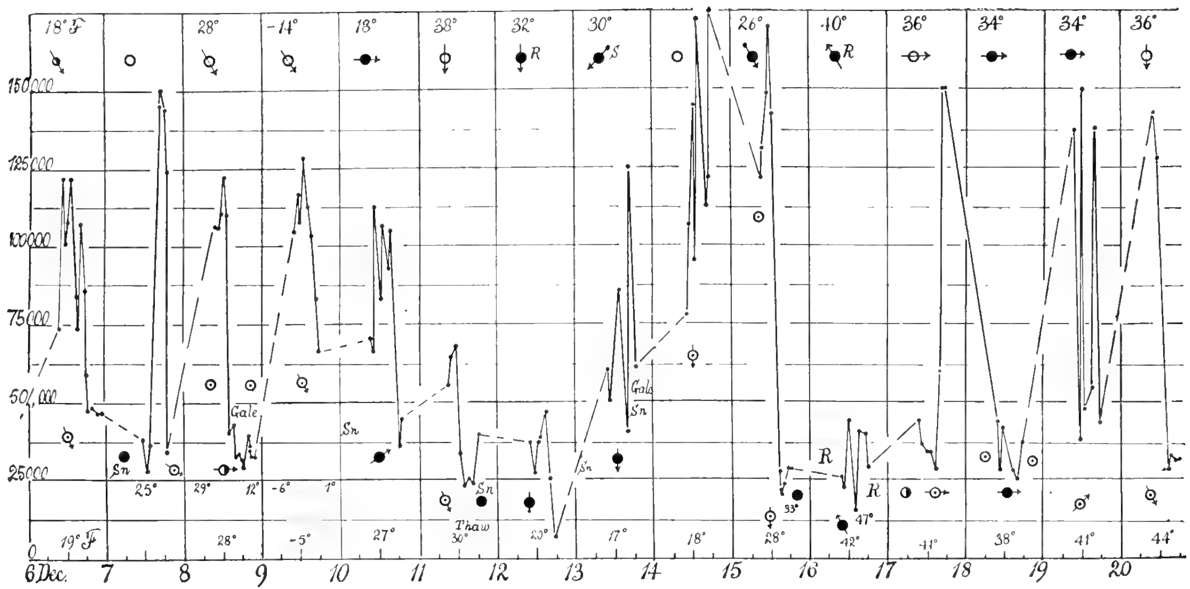


CHART 6.—NUCLEATION, DECEMBER 6 TO 20.

Data inserted as in the former case.

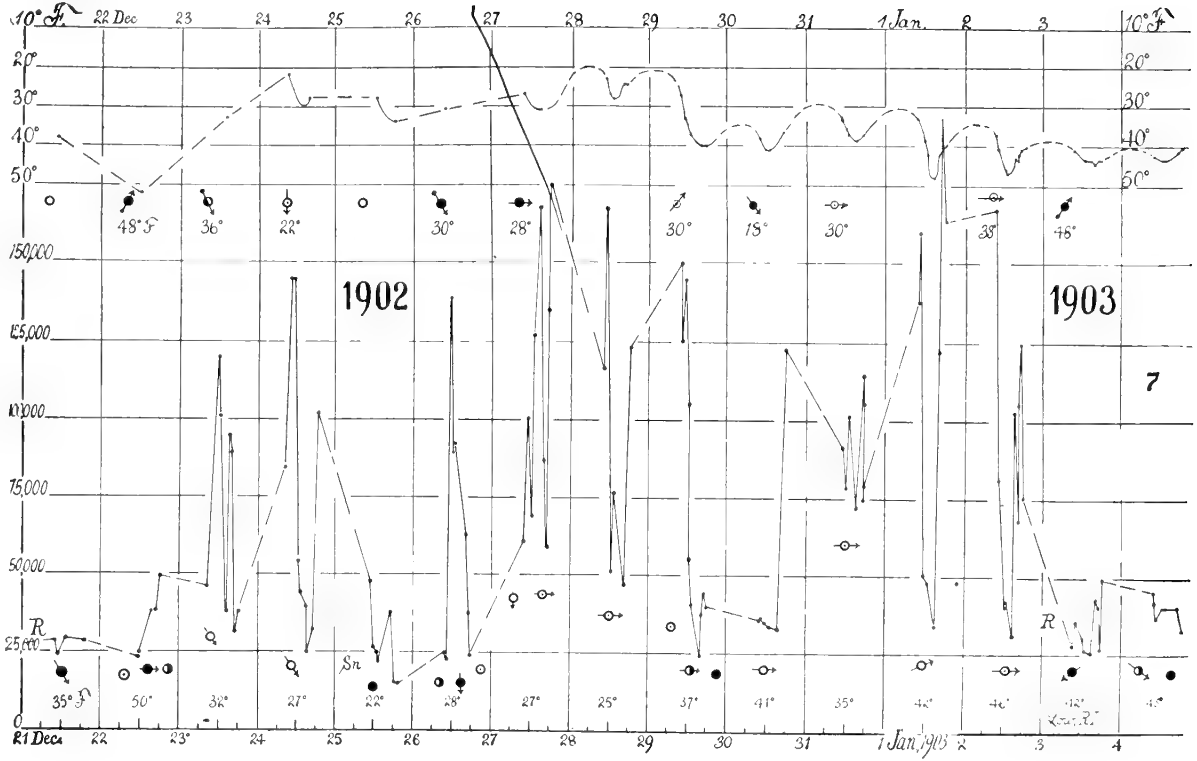


CHART 7.—NUCLEATION, DECEMBER 21, 1902, TO JANUARY 4, 1903, LOWER CURVE.

Temperature (degrees Fahrenheit) and winds (United States Weather Bureau) above curve. Local data nearer curve. Upper curve shows corresponding observed temperatures in degrees Fahrenheit, laid off positively downward.

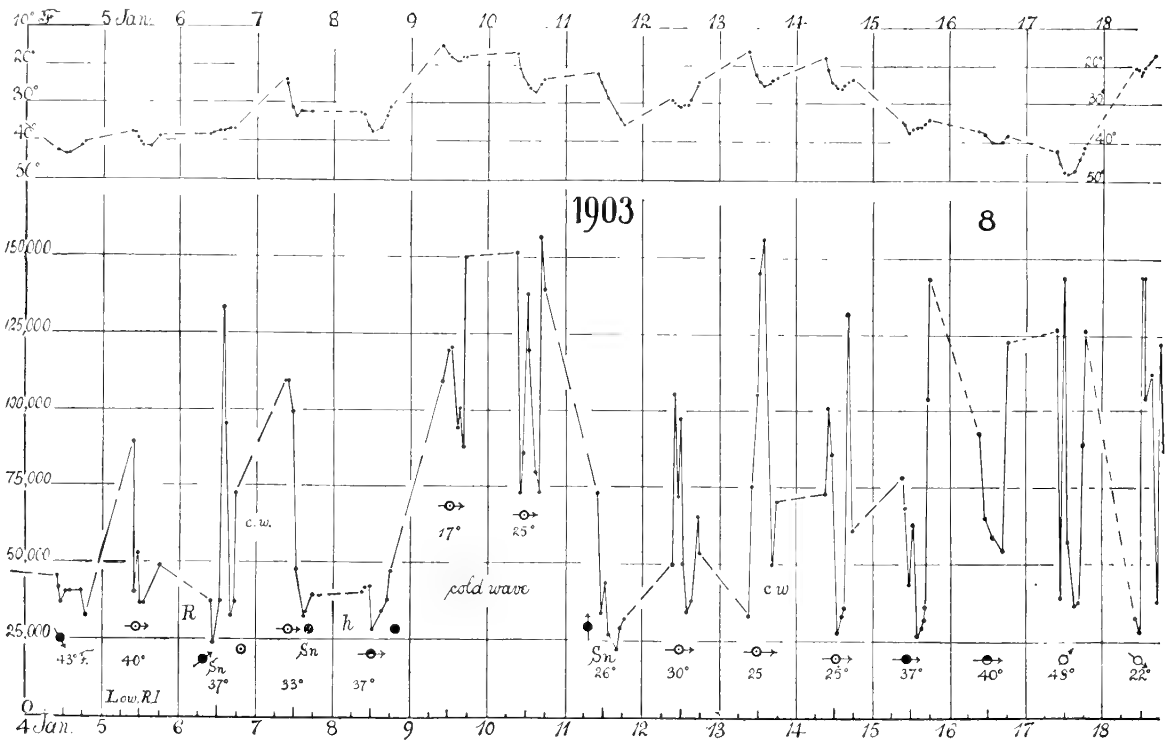
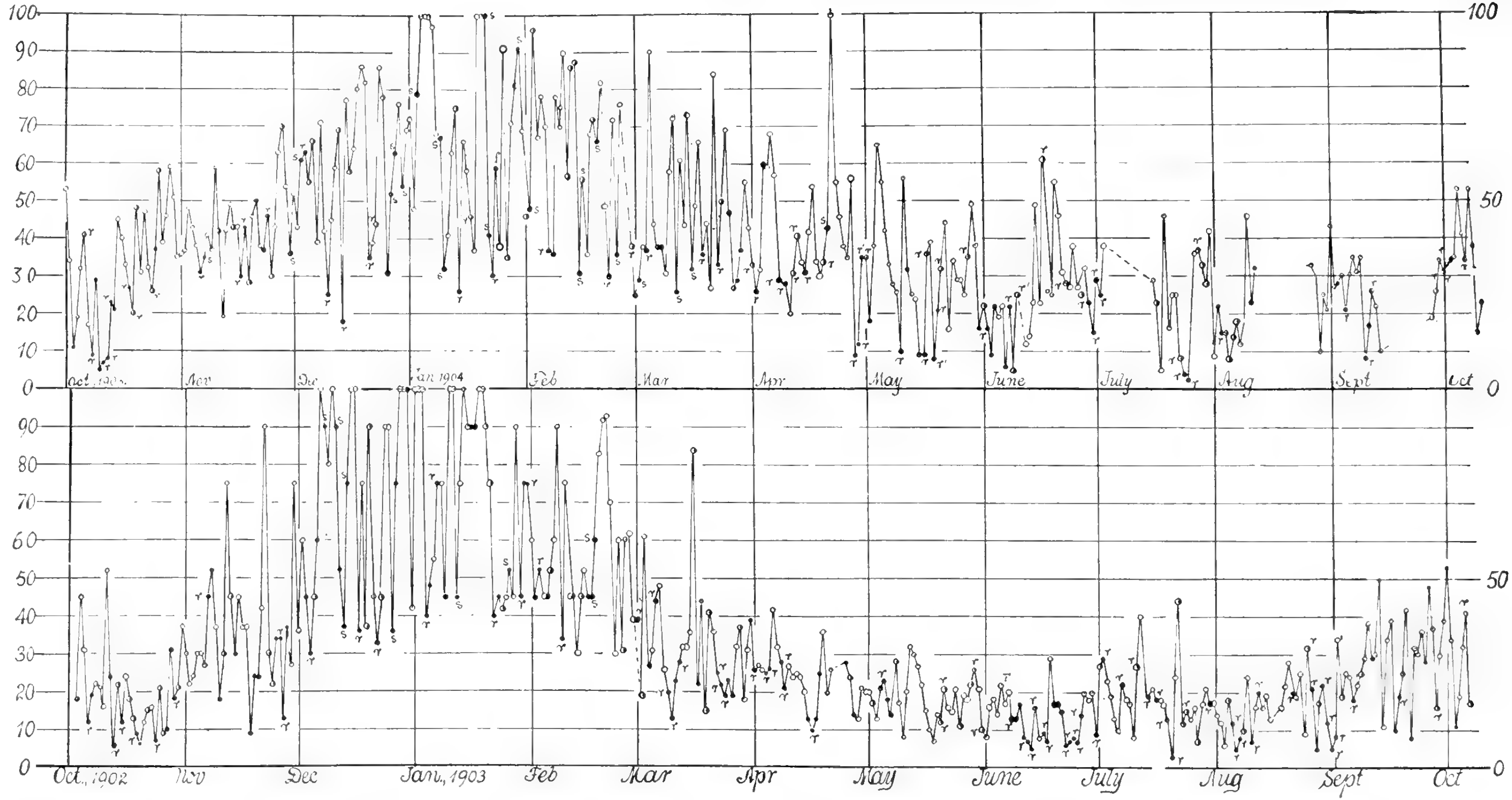


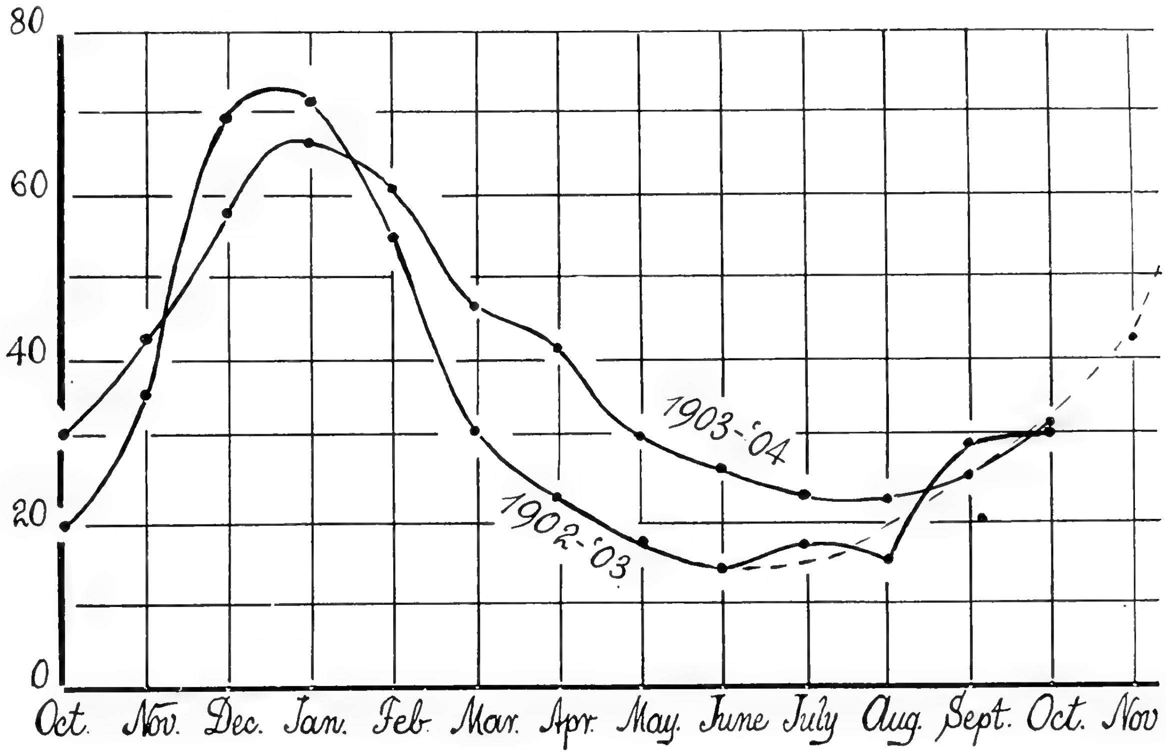
CHART 8.—NUCLEATION, JANUARY 4 TO 18, LOWER CURVE.

Local temperatures (degrees Fahrenheit, at about noon) accompany the curve. Upper curve, corresponding observed temperatures in degrees Fahrenheit.



CHARTS SHOWING AVERAGE NUMBER OF NUCLEI PER CUBIC CENTIMETER, ON SUCCESSIVE DAYS OF THE YEARS 1902-3 (LOWER CURVE) AND 1903-4 (UPPER CURVE).

The weather is given for each observation, ⊙ denoting clear, ◑ partly cloudy, ● cloudy, *r* rain, *sn* snow, *s* sun, etc.



CURVES SHOWING THE AVERAGE NUMBER OF NUCLEI PER CUBIC CENTIMETER IN SUCCESSIVE MONTHS OF THE YEARS 1902-3 AND 1903-4.

Points correspond to about the middle of the months. The winter maxima coincide approximately with the winter solstice. The summer minima are liable to be protracted by rains beyond the summer solstice. In 1902-3 the winter maximum falls off rapidly into the summer minimum.

PRESENT PROBLEMS OF INORGANIC CHEMISTRY.[a]

By Sir William Ramsay, K. C. B., F. R. S.

To discuss the "present problems of inorganic chemistry" is by no means an easy task. The expression might be taken to mean an account of what is being actually done at present by those engaged in inorganic research; or it might be taken to relate to what needs doing—to the direction in which research is required. To summarize what is being done in an intelligible manner in the time at my disposal would be an almost impossible task: hence I will choose the latter interpretation of the title of my address. Now, a considerable experience in attempting to unveil the secrets of nature has convinced me that a deliberate effort to discover some new law or fact seldom succeeds. The investigator generally begins unmethodically, by random and chance experiments; or perhaps he is guided by some indication which has struck his attention during some previous research; and he is often the plaything of circumstances in his choice. Experience leads him to choose problems which most readily admit of solution, or which appear likely to lead to the most interesting results. If I may be excused the egotism of referring to my own work, I may illustrate what I mean by relating the following curious coincidence: After Lord Rayleigh had announced his discovery that "atmospheric nitrogen" was denser than "chemical nitrogen," I referred to Cavendish's celebrated paper on the combination of the nitrogen and the oxygen of the air by means of electric sparks. Fortified by what I read, and by the knowledge gained during the performance of lecture experiments that red-hot magnesium is a good and fairly rapid absorbent of nitrogen, it was not long before a considerable quantity of nearly pure argon had been separated from atmospheric nitrogen. Now it happened that I possess two copies of Cavendish's works; and some months afterwards I consulted the other copy and found penciled on the margin the words "look into this." I remembered the circumstance which led to the annotation. About ten years before,

[a] An address at the International Congress of Arts and Science, St. Louis, September, 1904. Here printed by permission of the author.

one of my students had investigated the direct combination of nitrogen and hydrogen, and I had read Cavendish's memoir on that occasion. I mention this fact to show that for some reason which I forget, a line of work was not followed up, which would have been attended by most interesting results; one does not always follow the clue which yields results of the greatest interest. I regard it, therefore, as an impossible task to indicate the lines on which research should be carried out. All that I can do is to call attention to certain problems awaiting solution; but their relative importance must necessarily be a matter of personal bias, and others might with perhaps greater right suggest wholly different problems.

The fundamental task of inorganic chemistry is still connected with the classification of elements and compounds. The investigation of the classification of carbon compounds forms the field of organic chemistry, while general or physical chemistry deals with the laws of reaction and the influence of various forms of energy in furthering or hindering chemical change. And classification centers at present in the periodic arrangement of the elements, according to the order of their atomic weights. Whatever changes in our views may be concealed in the lap of the future, this great generalization, due to Newlands, Lothar Meyer, and Mendelejev, will always retain a place, perhaps the prominent place, in chemical science.

Now, it is certain that no attempt to reduce the irregular regularity of the atomic weights to a mathematical expression has succeeded; and it is, in my opinion, very unlikely that any such expression, of not insuperable complexity, and having a basis of physical meaning, will ever be found. I have already, in an address to the German Association at Cassel, given an outline of the grand problem which awaits solution. It can be shortly stated then: While the factors of kinetic and of gravitational energy, velocity, and momentum on the one hand and force and distance on the other are simply related to each other, the capacity factors of other forms of energy—surface, in the case of surface energy; volume, in the case of volume energy; entropy for heat; electric capacity, when electric charges are being conveyed by means of ions; atomic weight, when chemical energy is being gained or lost—all these are simply connected with the fundamental chemical capacity, atomic weight, or mass. The periodic arrangement is an attempt to bring the two sets of capacity factors into a simple relation to each other; and while the attempt is in so far a success, inasmuch as it is evident that some law is indicated, the divergences are such as to show that finality has not been attained. The central problem in inorganic chemistry is to answer the question, Why this incomplete concordance? Having stated the general question, it may conduce to clearness if some details are given.

1. The variation of molecular surface energy with temperature is

such that the surface energy for equal numbers of molecules distributed over a surface is equal for equal intervals of temperature below the temperature at which surface energy is zero—that is, the critical point. This gives a means of determining the molecular weights of liquids, and we assume that the molecular weight of a compound is accurately the sum of the atomic weights of the constituent elements.

2. The volume energy of gases is equal at equal temperature from that at which volume energy is zero—i. e., absolute zero. And it follows that those volumes of gases which possess equal volume energy contain equal numbers of molecules—again, a close connection with atomic weights.

3. The specific heats of elements are approximately inversely proportional to their atomic weights, and of compounds to the quotient of their molecular weights divided by the number of atoms in the molecule. Specific heat and entropy are closely related; hence one of the factors of thermal energy is proportional (nearly) to the reciprocal of the atomic weights.

4. The ion carries in its migration through a solution one or more electrons. Now, the ion is an atom carrying one or more charges—one for each equivalent. Here we have the capacity for electric charge proportional to the equivalent.

5. The factors of chemical energy are atomic weight and chemical potential; and as the former is identical numerically, or after multiplication by a simple factor with equivalent, electric potential is proportional to chemical potential.

We see, therefore, that surface, volume, thermal, electrical, and, no doubt, other forms of energy have as capacity factors magnitudes either identical with or closely related to units of chemical capacity while kinetic and linear energy are not so related, except through the periodic arrangement of the elements.

It appears, therefore, to be a fundamental problem for the chemist to ascertain, first, accurate atomic weights, and, second, to investigate some anomalies which still present difficulties. In America you have excellent workers in the former branch. Mallet, Morley, Richards, and many others have devoted their time and skill to perhaps the best work of this kind which has been done, and F. W. Clarke has collated all results and afforded incalculable help to all who work at or are interested in the subject. Valuable criticisms, too, have been made by Hinrichs; but it must be confessed that, in spite of these, which are perhaps the best determinations which have been made, the problem becomes more and not less formidable.

There are lines of work, however, which suggest themselves as possibly likely to throw light on the question. First, there is a striking anomaly in the atomic weight of nitrogen, determined by analysis

and determined by density. Stas obtained the number 14.04 (O=16), and Richards has recently confirmed his results, while Rayleigh and Leduc consistently obtained densities which, even when corrected so as to equalize the numbers of molecules in equal volumes, give the lower figure 14.002. The difference is 1 in 350—far beyond any possible experimental error. Recently an attempt to combine the two methods has led to a mean number, but that result can hardly be taken as final. What is the reason of the discrepancy? Its discovery will surely advance knowledge materially. I would suggest the preparation of pure compounds of nitrogen, such as salts of hydrazine, methylanine, etc., and their careful analysis, and also the accurate determination of the density and analysis of such gaseous compounds of nitrogen as nitric oxide and peroxide. I have just heard from my former student, W. R. W. Gray, that he has recovered Stas's number by combining 2NO with O_2, while the density of NO leads to the lower value for the atomic weight of nitrogen.

The question of the atomic weight of tellurium appears to be settled, at least so far as its position with regard to the generally accepted atomic weight of iodine is concerned. Recent determinations give the figures 127.5 (Gutbier), 127.6 (Pellini), and 127.9 (Köthner). But is that of iodine as accurately known? It would appear advisable to revise the determination of Stas, preparing the iodine preferably from an organic compound, such as iodoform, which can be produced in a high state of purity. The heteromorphism of selenates and tellurates, too, has recently been demonstrated, and it may be questioned whether these elements should both belong to the same group.

The rare earths still remain a puzzle. Their number is increasing yearly, and their claim to individuality admits of less and less dispute. What is to be done with them? Are they to be grouped by themselves as Brauner and Steele propose? If so, how is their connection with the other elements to be explained? Recent experiments in my laboratory have convinced me that in the case of thorium, at least, ordinary tests of purity, such as fine crystals, constant subliming point, etc., do not always indicate homogeneity; or else that we are sadly in want of some analytical method of sufficient accuracy. The change of thorium into thorium X is perhaps hardly an explanation of the divergencies; yet it must be considered; but of this, more anon.

To turn next to another problem closely related to the orderly arrangement of the elements, that of valency, but little progress can be chronicled. The suggestions which have been made are speculative rather than based on experiment. The existence of many peroxidized substances, such as percarbonates, perborates, persulphates and of crystalline compounds of salts with hydrogen peroxide, makes it difficult to draw any indisputable conclusions as regards valency from

a consideration of oxygen compounds. Moissan's brilliant work on fluorides, however, has shown that SF_6 is capable of stable existence, and this forms a strong argument in support of the hexad character of sulphur. The tetravalency of oxygen, under befitting conditions, too, is being acknowledged, and this may be reconciled with the existence of water of crystallization, as well as of the per-salts already mentioned. The adherence of ammonia to many chlorides, nitrates, etc., points to the connecting link being ascribable to the pentavalency of nitrogen; and it might be worth while investigating similar compounds with phosphoretted and arsenicorretted hydrogen, especially at low temperatures.

The progress of chemical discovery, indeed, is closely connected with the invention of new methods of research, or the submitting of matter to new conditions. While Moissan led the way by elaborating the electric furnace, and thus obtained a potent agent in temperatures formerly unattainable, Spring has tried the effect of enormous pressure, and has recently found chemical action between cuprous oxide and sulphur at ordinary temperature, provided the pressure be raised to 8,000 atmospheres. Increase of pressure appears to lower the temperature of reaction. It has been known for long that explosions will not propagate in rarefied gases, and that they became more violent when the reacting gases are compressed; but we are met with difficulties, such as the noncombination of hydrogen and nitrogen, even at high temperature and great pressure; yet it is possible to measure the electromotive force (0.59 volt) in a couple consisting of gaseous nitrogen and gaseous hydrogen, the electrolyte being a solution of ammonium nitrate saturated with ammonia. Chemical action between dissolved hydrogen and nitrogen undoubtedly occurs; but it is not continuous. Again we may ask, Why? The heat evolution should be great; the gain of entropy should also be high were direct combination to occur. Why does it not occur to any measurable extent? Is it because for the initial stages of any chemical reaction the reacting molecules must be already dissociated and those of nitrogen are not? Is that in any way connected with the abnormally low density of gaseous nitrogen? Or is it that, in order that combination shall occur, the atoms must fit each other; and that in order that nitrogen and hydrogen atoms may fit they must be greatly distorted? But these are speculative questions, and it is not obvious how experiments can be devised to answer them.

Many compounds are stable at low temperatures which dissociate when temperature is raised. Experiments are being made, now that liquid air is to be purchased or cheaply made, on the combinations of substances which are indifferent to each other at ordinary temperatures. Yet the research must be a restricted one, for most substances are solid at —185°, and refuse to act on each other. It is probable,

however, that at low temperatures compounds could be formed in which one of the elements would possess a greater valency than that usually ascribed to it; and also that double compounds of greater complexity would prove stable. Valency, indeed, appears to be in many cases a function of temperature; exothermic compounds, as is well known, are less stable the higher the temperature. The sudden cooling of compounds produced at a high temperature may possibly result in forms being preserved which are unstable at ordinary temperatures. Experiments have been made in the hope of obtaining compounds of argon and helium by exposing various elements to the influence of sparks from a powerful induction coil, keeping the walls of the containing vessel at the temperature of liquid air, in the hope that any endothermic compound which might be formed would be rapidly cooled and would survive the interval of temperature at which decomposition would take place naturally. But these experiments have so far yielded only negative results. There is some indication, however, that such compounds are stable at 1,500°. It might be hoped that a study of the behavior of the nonvalent elements would have led to some conception of the nature of valency, but so far no results bearing on the question have transpired. The condition of helium in the minerals from which it is obtainable by heat is not explained, and experiments in this direction have not furnished any positive information. It is always doubtful whether it is advisable to publish the results of negative experiments, for it is always possible that some more skilled or more fortunate investigator may succeed where one has failed. But it may be chronicled that attempts to cause combination between the inactive gases and lithium, potassium, rubidium, and caesium have yielded no positive results, nor do they appear to react with fluorine. Yet conditions of experiment play a leading part in causing combinations, as has been well shown by Moissan with the hydrides of the alkali metals, and by Guntz, with those of the metals of the alkaline earths. The proof that sodium hydride possesses the formula NaH, instead of the formerly accepted one, removes one difficulty in the problem of valency, and SrH_2 falls into its natural position among hydrides.

A fertile field of inorganic research lies in the investigation of structure. While the structure of organic compounds has been elucidated almost completely, that of inorganic compounds is practically undeveloped. Yet efforts have been made in this direction which appear to point a way. The nature of the silicates has been the subject of research for many years by F. W. Clarke, and the way has been opened. Much may be done by treating silicates with appropriate solvents, acid or alkaline, which differentiate between uncombined and combined silica, and which in some cases, by replacement of one metal by another, gives a clue to constitution. The complexity of the

molecules of inorganic compounds, which are usually solid, forms another bar to investigation. It is clear that sulphuric acid, to choose a common instance, possesses a very complicated molecule, and the fused nitrates of sodium and potassium are not correctly represented by the simple formulæ $NaNO_3$ and KNO_3. Any theory of the structure of their derivatives must take such facts into consideration; but we appear to be getting nearer the elucidation of the molecular weights of solids. Again, the complexity of solutions of the most common salts is maintained by many investigators. For example, a solution of cobalt chloride, while it undoubtedly contains, among other constituents, simple molecules of $CoCl_2$, also consists of ions of a complex character, such as $(CoCl_4)''$. And what holds for cobalt chloride also undoubtedly holds for many similar compounds.

In determining the constitution of the compounds of carbon, stereochemistry has played a great part. The ordinary structural formulæ are now universally acknowledged to be only pictorial, if, indeed, that word is legitimate. Perhaps it would be better to say that they are distorted attempts at pictures, the drawing of which is entirely free from all rules of perspective. But these formulæ may in almost every case be made nearly true pictures of the configuration of the molecules. The benzine formula, to choose an instance which is by no means the simplest, has been shown by Collie to be imitated by a model which represents in an unstrained manner the behavior of that body on treatment with reagents. But in the domain of inorganic chemistry little progress has been made. Some ingenious ideas of the geologist Sollas on this problem have hardly received the attention which they deserve. Perhaps they may have been regarded as too speculative. On the other hand, Le Bel's and Pope's proof of the stereo-isomerism of certain compounds of nitrogen, Pope's demonstration of the tetrahedral structure of the alkyl derivatives of tin, and Smiles's syntheses of stereo-isomeric sulphur compounds give us the hope that further investigation will lead to the classification of many other elements from this point of view. Indeed, the field is almost virgin soil, but it is well worth while cultivating. There is no doubt that the investigation of other organo-metallic compounds will result in the discovery of stereo-isomerides; yet the methods of investigation capable of separating such constituents have in most cases still to be discovered.

The number of chemical isomerides among inorganic compounds is a restricted one. Werner has done much to elucidate this subject in the case of complex ammonia derivatives of metals and their salts; but there appears to be little doubt that if looked for, the same or similar phenomena would be discoverable in compounds with much simpler formulæ. The two forms of So_3, sulphuric anhydride, are an instance in point. No doubt formation under dif-

ferent conditions of temperature and pressure might result in the greater stability of some forms which under our ordinary conditions are changeable and unstable. The fact that under higher pressures than are generally at our disposal different forms of ice have been proved to exist, and the application of the phase rule to such cases, will greatly enlarge our knowledge of molecular isomerism.

The phenomena of catalysis have been extensively studied of recent years, and have obviously an important bearing on such problems. A catalytic agent is one which accelerates or retards the velocity of reaction. Without inquiring into the mechanism of catalysis, its existence may be made to influence the rate of chemical change and to render stable bodies which under ordinary conditions are unstable. For if it is possible to accelerate a chemical change in such a way that the usually slow and possibly unrecognizable rate of isomeric change may be made apparent and measurable, a substance the existence of which could not be recognized under ordinary circumstances, owing to its infinitesimal amount, may be induced to exist in weighable quantity if the velocity of its formation from an isomeride can be greatly accelerated by the presence of an appropriate catalytic agent. I am not aware that attempts have been made in this direction. The discovery of catalytic agents is, as a rule, the result of accident. I do not think that any guide exists which would enable us to predict that any particular substance would cause an acceleration or a retardation of any particular reaction. But catalytic agents are generally those which themselves, by their power of combining with or parting with oxygen, or some other element, cause the transfer of that element to other compounds to take place with increased or diminished velocity. It is possible, therefore, to cause ordinary reactions to take place in presence of a third body, choosing the third body with a view to its catalytic action, and to examine carefully the products of the main reaction as regards their nature and their quantity. Attempts have been made in this direction with marked success; the rate of change of hydrogen dioxide, for example, has been fairly well studied. But what has been done for that compound may be extended indefinitely to others, and, doubtless, with analogous results. Indications of the existence of as yet undiscovered compounds may be derived from a study of physical, and particularly of electrical, changes. There appears to be sufficient evidence of an oxide of hydrogen containing more oxygen than hydrogen dioxide, from a study of the electromotive force of a cell containing hydrogen dioxide; yet the higher oxide still awaits discovery.

The interpretation of chemical change in the light of the ionic

theory may now be taken as an integral part of inorganic chemistry. The ordinary reactions of qualitative and quantitative analysis are now almost universally ascribed to the ions, not to the molecules. And the study of the properties of most ions falls into the province of the inorganic chemist. To take a familiar example: The precipitation of hydroxides by means of ammonia solution has long led to the hypothesis that the solution contained ammonium hydroxide, and, indeed, the teaching of the text-books and the labels on the bottles supported this view. But we know now that a solution of ammonia in water is a complex mixture of liquid ammonia and liquid water; of ammonium hydroxide, NH_4OH; and of ions of ammonium $(NH_4)'$, and hydroxyl $(OH)'$. Its reactions, therefore, are those of such a complex mixture. If brought into contact with a solution of some substance which will withdraw the hydroxyl ions, converting them into water, or into some nonionized substance, they are replaced at the expense of the molecules of nonionized ammonium hydroxide; and these, when diminished in amount, draw on the store of molecules of ammonia and water, which combine, so as to maintain equilibrium. Now, the investigation of such changes must belong to the domain of inorganic chemistry. It is true that the methods of investigation are borrowed from the physical chemist; but the products lie in the province of the inorganic chemist. Indeed, the different departments of chemistry are so interlaced that it is impossible to pursue investigations in any one branch without borrowing methods from the others; and the inorganic chemist must be familiar with all chemistry if he is to make notable progress in his own branch of the subject. And if the substances and processes investigated by the inorganic chemist are destined to become commercially important, it is impossible to place the manufacturer on a sound commercial basis without ample knowledge of physical methods and their application to the most economical methods of accelerating certain reactions and retarding others, so as to obtain the largest yield of the required product at the smallest cost of time, labor, and money.

I have endeavored to sketch some of the aspects of inorganic chemistry with a view to suggesting problems for solution, or at least the directions in which such problems are to be sought. But the developments of recent years have been so astonishing and so unexpected that I should fail in my duty were I not to allude to the phenomena of radio-activity and their bearing on the subject of my address. It is difficult to gauge the relative importance of investigations in this field; but I may be pardoned if I give a short account of what has already been done and point out lines of investigation which appear to me likely to yield useful results.

The wonderful discovery of radium by Madame Curie, the prepara-

tion of practically pure compounds of it, and the determination of its atomic weight are familiar to all of you. Her discovery of polonium, and Debierne's of actinium have also attracted much attention. The recognition of the radio-activity of uranium by Becquerel, which gave the first impulse to these discoveries, and of that of thorium by Schmidt is also well known.

These substances, however, presented at first more interest for the physicist than the chemist, on account of the extraordinary power which they all possess of emitting "rays." At first these rays were supposed to constitute ethereal vibrations, but all the phenomena were not explicable on that supposition. Schmidt first, and Rutherford and Soddy later, found that certain so-called "rays" really consist of gases, and that while thorium emits one kind radium emits another, and no doubt Debierne's actinium emits a third. The name "emanations" was applied by Rutherford to such radio-active bodies. He and Soddy found that those of radium and thorium could be condensed and frozen by exposure to the temperature of liquid air, and that they were not destroyed or altered in any way by treatment with agents which are able to separate all known gases from those of the argon group, namely, red-hot magnesium lime, and it was later found that sparking with oxygen in presence of caustic potash did not affect the gaseous emanation from radium. The conclusion therefore followed that in all probability these bodies are gases of the argon group, the atomic weight of which, and consequently the density, is very high. Indeed, several observers, by means of experiments on the rate of diffusion of the gas from radium, believe it to have a density of approximately 100, referred to the hydrogen standard. This conclusion has been confirmed by the mapping of the spectrum of the radium emanation, which is similar in general character to the spectra of the inactive gases, consisting of a number of well-defined, clearly cut brilliant lines, standing out from a black background. The volume of the gas produced spontaneously from a given weight of radium bromide in a given time has been measured; and it was incidentally shown that this gas obeys Boyle's law of pressures. The amount of gas thus collected and measured, however, was very minute; the total quantity was about the forty-thousandth of a cubic centimeter.

Having noticed that those minerals which consist of compounds of uranium and thorium contain helium, Rutherford and Soddy made the suggestion that it might not be impossible that helium is the product of the spontaneous change of the emanation; and Soddy and I were able to show that this is actually the case. For, first, when a quantity of a radium salt which has been prepared for some time is dissolved in water the occluded helium is expelled and can be recog-

nized by means of its spectrum; further, the fresh emanation shows no helium spectrum, but after a few days the spectrum of helium begins to appear, proving that a spontaneous change is in progress; and last, as the emanation disappears its volume decreases to zero; and on heating the capillary glass tube which contained it, helium is driven out from the glass walls, into which its molecules had been embedded in volume equal to three and a half times that of the emanation. The α-rays, as foreshadowed by Rutherford and Soddy, consist of helium particles.

All these facts substantiate the theory, devised by Rutherford and Soddy, that the radium atom is capable of disintegration, one of the products being a gas, which itself undergoes further disintegration, forming helium as one of its products. Up till now the sheet anchor of the chemists has been the atom. But the atom itself appears to be complex, and to be capable of decomposition. It is true that only in the case of a very few elements, and these of high atomic weight, has this been proved. But even radium, the element which has by far the most rapid rate of disintegration, has a comparatively long life; the period of half-change of any given mass of radium is approximately eleven hundred years. The rate of change of the other elements is incomparably slower. This change, too, at least in the case of radium, and its emanation, and presumably also in the case of other elements, is attended with an enormous loss of energy. It is easy to calculate from heat measurements (and independent and concordant measurements have been made) that 1 pound of emanation is capable of parting with as much energy as several hundred tons of nitroglycerine. The order of the quantity of energy evolved during the disintegration of the atom is as astonishing as the nature of the change. But the nature of the change is parallel to what would take place if an extremely complicated hydrocarbon were to disintegrate; its disruption into simpler paraffins and olefines would also be attended with loss of energy. We may therefore take it, I think, that the disintegration hypothesis of Rutherford and Soddy is the only one which will meet the case.

If radium is continually disappearing, and would totally disappear in a very few thousand years, it follows that it must be reproduced from other substances, at an equal rate. The most evident conjecture, that it is formed from uranium, has not been substantiated. Soddy has shown that salts of uranium, freed from radium, and left for a year, do not contain one ten-thousandth part of the radium that one would expect to be formed in the time. It is evident, therefore, that radium must owe its existence to the presence of some other substances, but what they are is still unascertained.

During the investigation of Rutherford and Soddy of the thorium

emanation, a most interesting fact was observed, namely, that precipitation of the thorium as hydroxide by ammonia left unprecipitated a substance, which they termed "thorium-X," and which was itself highly radio-active. Its radio-active life, however, was a short one; and as it decayed, it was reproduced from its parent thorium at an equal rate. Here is a case analogous to what was sought for with radium and uranium; but evidently uranium is not the only parent of radium; the operation is not one of parthenogenesis. Similar facts have been elicited for uranium by Crookes.

The α-rays, caused by the disintegration of radium and of its emanation, are accompanied by rays of quite a different character; they are the β-rays, identical with electrons, the mass of which has been measured by J. J. Thomson and others. These particles are projected with enormous velocity, and are capable of penetrating glass and metal screens. The power of penetration appears to be proportional to the amount of matter in the screen, estimated by its density. These electrons are not matter; but, as I shall relate, they are capable of causing profound changes in matter.

For the past year a solution of radium bromide has been kept in three glass bulbs, each connected to a Topler pump by means of capillary tubing. To insure these bulbs against accident each was surrounded by a small beaker; it happened that one of these beakers consisted mainly of potash glass; the other two were of soda glass. The potash-glass beaker became brown, while the two soda-glass beakers became purple. I think there is every probability that the colors are due to liberation of the metals potassium and sodium in the glass. They are contained in that very viscous liquid, glass, in the colorless ionic state; but these ions are discharged by the β-rays or negative electrons, and each metal imparts its own peculiar color to the glass, as has been shown by Maxwell Garnett. This phenomenon, however interesting, is not the one to which I desire to draw special attention. It must be remembered that the beakers have been exposed only to β-rays; α-rays have never been in contact with them; they have never been bombarded by what is usually called matter, except by the molecules of the surrounding air. Now, these colored beakers are radio-active, and the radio-active film dissolves in water. After careful washing, the glass was no longer radio-active. The solution contains an emanation, for on bubbling air through it, and cooling the issuing air with liquid air, part of the radio-active matter was retained in the cooled tube. This substance can be carried into an electroscope by a current of air, after the liquid air has been withdrawn, and as long as the air current passes, the electroscope is discharged; the period of decay of this emanation, however, is very rapid, and on ceasing the current of air, the leaves of

the electroscope cease to be discharged. In having such a short period of existence, this emanation resembles the one from actinium.

Owing to the recess, only a commencement has been made with the investigation of the residue left on evaporation of the aqueous solution. On evaporation, the residue is strongly active. Some mercurous nitrate was then added to the dissolved residue, and it was treated with hydrochloric acid in excess, to precipitate mercurous chloride. The greater part of the active matter was thrown down with the mercurous chloride, hence it appears to form an insoluble chloride. The mercurous chloride retained its activity unchanged in amount for ten days. The filtrate from the mercurous chloride, on evaporation, turned out to be active; and on precipitating mercuric sulphide in it, the sulphide precipitate was also active; but its activity decayed in one day. The filtrate from the mercuric sulphide gave inactive precipitates with ferric salts and ammonia, with zinc salts and ammonium sulphide, with calcium salts and ammonium carbonate: and on final evaporation the residue was not radio-active. Hence the active matter forms an insoluble chloride and sulphide. The precipitated mercurous chloride and mercuric sulphide were dissolved in aqua regia, and the solution was evaporated. The residue was dissolved in water, and left the dish inactive. But the solution gave an insoluble sulphate, when barium chloride and sulphuric acid were added to it, hence the radio-active element forms an insoluble sulphate, as well as an insoluble chloride and sulphide.

This is a sample of the experiments which have been made. It may be remarked that the above results were obtained from a mixture of the potash and soda glass; somewhat different results were obtained from the potash glass alone. These changes appear to be due to the conversion of one or more of the constituents of the glass into other bodies. Needless to say, neither of the samples of glass contained lead.

I have mentioned these experiments in detail, because I think they suggest wholly new lines of investigation. It would appear that if energy can be poured into a definite chemical matter, such as glass, it undergoes some change, and gives rise to bodies capable of being tested, for I imagine that radio-active forms of matter are produced, either identical with or allied to those at present known. And just as radium and other radio-active elements suffer degradation spontaneously, evolving energy, so I venture to think that if energy be concentrated in the molecules of ordinary forms of matter, a sort of polymerization is the result, and radio-active elements, probably elements with high atomic weight, and themselves unstable, are formed. Of course further research may greatly modify these views; but some guide is necessary, and Mr. Ternent Cook, who has helped me in these

experiments, and I suggest this hypothesis (in the words of Dr. Johnstone Stoney, a hypothesis is "a supposition which we hope may be useful") to serve as a guide for future endeavor.

In the light of such facts, speculation on the periodic arrangement of the elements is surely premature. It is open to anyone to make suggestions; they are self-evident. Most of you will agree with the saying, "It is easy to prophesy after the event." I prefer to wait until prophecy becomes easy.

I must ask your indulgence for having merely selected a few out of the many possible views as regards the problems of inorganic chemistry. I can only plead in excuse that my task is not an easy one; and I venture to express the hope that some light has been thrown on the shady paths which penetrate that dark region which we term the future.

EVOLUTION OF THE SCIENTIFIC INVESTIGATOR.[a]

By Simon Newcomb.

As we look at the assemblage gathered in this hall, comprising so many names of widest renown in every branch of learning—we might almost say in every field of human endeavor—the first inquiry suggested must be after the object of our meeting. The answer is that our purpose corresponds to the eminence of the assemblage. We aim at nothing less than a survey of the realm of knowledge, as comprehensive as is permitted by the limitations of time and space. The organizers of our congress have honored me with the charge of presenting such preliminary view of its field as may make clear the spirit of our undertaking.

Certain tendencies characteristic of the science of our day clearly suggest the direction of our thoughts most appropriate to the occasion. Among the strongest of these is one toward laying greater stress on questions of the beginning of things, and regarding a knowledge of the laws of development of any object of study as necessary to the understanding of its present form. It may be conceded that the principle here involved is as applicable in the broad field before us as in a special research into the properties of the minutest organism. It therefore seems meet that we should begin by inquiring what agency has brought about the remarkable development of science to which the world of to-day bears witness. This view is recognized in the plan of our proceedings by providing for each great department of knowledge a review of its progress during the century that has elapsed since the great event commemorated by the scenes outside this hall. But such reviews do not make up that general survey of science at large which is necessary to the development of our theme, and which must include the action of causes that had their origin long before our time. The movement which culminated in making the nineteenth century ever memorable in history is the outcome of a long series of causes, acting through many centuries, which are worthy

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of especial attention on such an occasion as this. In setting them forth we should avoid laying stress on those visible manifestations which, striking the eye of every beholder, are in no danger of being overlooked, and search rather for those agencies whose activities underlie the whole visible scene, but which are liable to be blotted out of sight by the very brilliancy of the results to which they have given rise. It is easy to draw attention to the wonderful qualities of the oak; but, from that very fact, it may be needful to point out that the real wonder lies concealed in the acorn from which it grew.

Our inquiry into the logical order of the causes which have made our civilization what it is to-day will be facilitated by bringing to mind certain elementary considerations—ideas so familiar that setting them forth may seem like citing a body of truisms—and yet so frequently overlooked, not only individually, but in their relation to each other, that the conclusion to which they lead may be lost to sight. One of these propositions is that psychical rather than material causes are those which we should regard as fundamental in directing the development of the social organism. The human intellect is the really active agent in every branch of endeavor—the primum mobile of civilization—and all those material manifestations to which our attention is so often directed are to be regarded as secondary to this first agency. If it be true that "in the world is nothing great but man; in man is nothing great but mind," then should the key-note of our discourse be the recognition of this first and greatest of powers.

Another well-known fact is that those applications of the forces of nature to the promotion of human welfare which have made our age what it is are of such comparatively recent origin that we need go back only a single century to antedate their most important features, and scarcely more than four centuries to find their beginnig. It follows that the subject of our inquiry should be the commencement, not many centuries ago, of a certain new form of intellectual activity.

Having gained this point of view, our next inquiry will be into the nature of that activity and its relation to the stages of progress which preceded and followed its beginning. The superficial observer, who sees the oak but forgets the acorn, might tell us that the special qualities which have brought out such great results are expert scientific knowledge and rare ingenuity, directed to the application of the powers of steam and electricity. From this point of view the great inventors and the great captains of industry were the first agents in bringing about the modern era. But the more careful inquirer will see that the work of these men was possible only through a knowledge of the laws of nature, which had been gained by men whose work took precedence of theirs in logical order, and that

success in invention has been measured by completeness in such knowledge. While giving all due honor to the great inventors, let us remember that the first place is that of the great investigators, whose forceful intellects opened the way to secrets previously hidden from men. Let it be an honor and not a reproach to these men that they were not actuated by the love of gain, and did not keep utilitarian ends in view in the pursuit of their researches. If it seems that in neglecting such ends they were leaving undone the most important part of their work, let us remember that nature turns a forbidding face to those who pay her court with the hope of gain, and is responsive only to those suitors whose love for her is pure and undefiled. Not only is the special genius required in the investigator not that generally best adapted to applying the discoveries which he makes, but the result of his having sordid ends in view would be to narrow the field of his efforts and exercise a depressing effect upon his activities. The true man of science has no such expression in his vocabulary as "useful knowledge." His domain is as wide as nature itself, and he best fulfills his mission when he leaves to others the task of applying the knowledge he gives to the world.

We have here the explanation of the well-known fact that the functions of the investigator of the laws of nature and of the inventor who applies these laws to utilitarian purposes are rarely united in the same person. If the one conspicuous exception which the past century presents to this rule is not unique, we should probably have to go back to Watt to find another.

From this viewpoint it is clear that the primary agent in the movement which has elevated man to the masterful position he now occupies is the scientific investigator. He it is whose work has deprived plague and pestilence of their terrors, alleviated human suffering, girdled the earth with the electric wire, bound the continent with the iron way, and made neighbors of the most distant nations. As the first agent which has made possible this meeting of his representatives, let his evolution be this day our worthy theme. As we follow the evolution of an organism by studying the stages of its growth, so we have to show how the work of the scientific investigator is related to the ineffectual efforts of his predecessors.

In our time we think of the process of development in nature as one going continuously forward through the combination of the opposite processes of evolution and dissolution. The tendency of our thought has been in the direction of banishing cataclysms to the theological limbo and viewing nature as a sleepless plodder, endowed with infinite patience, waiting through long ages for results. I do not contest the truth of the principle of continuity on which this view is based. But it fails to make known to us the whole truth. The building of a ship from the time that her keel is laid until she is making

her way across the ocean is a slow and gradual process; yet there is a cataclysmic epoch opening up a new era in her history. It is the moment when, after lying for months or years a dead, inert, immovable mass, she is suddenly endowed with the power of motion, and, as if imbued with life, glides into the stream, eager to begin the career for which she was designed.

I think it is thus in the development of humanity. Long ages may pass during which a race, to all external observation, appears to be making no real progress. Additions may be made to learning and the records of history may constantly grow, but there is nothing in its sphere of thought or in the features of its life that can be called essentially new. Yet nature may have been all along slowly working in a way which evades our scrutiny until the result of her operations suddenly appears in a new and revolutionary movement, carrying the race to a higher plane of civilization.

It is not difficult to point out such epochs in human progress. The greatest of all, because it was the first, is one of which we find no record either in written or geological history. It was the epoch when our progenitors first took conscious thought of the morrow, first used the crude weapons which nature had placed within their reach to kill their prey, first built a fire to warm their bodies and cook their food. I love to fancy that there was some one first man, the Adam of evolution, who did all this, and who used the power thus acquired to show his fellows how they might profit by his example. When the members of the tribe or community which he gathered around him began to conceive of life as a whole—to include yesterday, to-day, and to-morrow in the same mental grasp—to think how they might apply the gifts of nature to their own uses, a movement was begun which should ultimately lead to civilization.

Long indeed must have been the ages required for the development of this rudest primitive community into the civilization revealed to us by the most ancient tablets of Egypt and Assyria. After spoken language was developed, and after the rude representation of ideas by visible marks drawn to resemble them had long been practiced, some Cadmus must have invented an alphabet. When the use of written language was thus introduced, the word of command ceased to be confined to the range of the human voice, and it became possible for master minds to extend their influence as far as a written message could be carried. Then were communities gathered into provinces, provinces into kingdoms, kingdoms into the great empires of antiquity. Then arose a stage of civilization which we find pictured in the most ancient records—a stage in which men were governed by laws that were perhaps as wisely adapted to their conditions as our laws are to ours—in which the

phenomena of nature were rudely observed, and striking occurrences in the earth or in the heavens recorded in the annals of the nation.

Vast was the progress of knowledge during the interval between these empires and the century in which modern science began. Yet, if I am right in making a distinction between the slow and regular steps of progress, each growing naturally out of that which preceded it, and the entrance of the mind at some fairly definite epoch into an entirely new sphere of activity, it would appear that there was only one such epoch during the entire interval. This was when abstract geometrical reasoning commenced, and astronomical observations aiming at precision were recorded, compared, and discussed. Closely associated with it must have been the construction of the forms of logic. The radical difference between the demonstration of a theorem of geometry and the reasoning of everyday life which the masses of men must have practiced from the beginning, and which few even to-day ever get beyond, is so evident at a glance that I need not dwell upon it. The principal feature of this advance is that, by one of those antinomies of the human intellect of which examples are not wanting even in our time, the development of abstract ideas preceded the concrete knowledge of natural phenomena. When we reflect that in the geometry of Euclid the science of space was brought to such logical perfection that even to-day its teachers are not agreed as to the practicability of any great improvement upon it, we can not avoid the feeling that a very slight change in the direction of the intellectual activity of the Greeks would have led to the beginning of natural science. But it would seem that the very purity and perfection which was aimed at in their system of geometry stood in the way of any extension or application of its methods and spirit to the field of nature. One example of this is worthy of attention. In modern teaching the idea of magnitude as generated by motion is freely introduced. A line is described by a moving point; a plane by a moving line; a solid by a moving plane. It may, at first sight, seem singular that this conception finds no place in the Euclidian system. But we may regard the omission as a mark of logical purity and rigor. Had the real or supposed advantages of introducing motion into geometrical conceptions been suggested to Euclid, we may suppose him to have replied that the theorems of space are independent of time; that the idea of motion necessarily implies time, and that, in consequence, to avail ourselves of it would be to introduce an extraneous element into geometry.

It is quite possible that the contempt of the ancient philosophers for the practical application of their science, which has continued in some form to our own time, and which is not altogether unwhole-

some, was a powerful factor in the same direction. The result was that, in keeping geometry pure from ideas which did not belong to it, it failed to form what might otherwise have been the basis of physical science. Its founders missed the discovery that methods similar to those of geometric demonstration could be extended into other and wider fields than that of space. Thus, not only the development of applied geometry, but the reduction of other conceptions to a rigorous mathematical form was indefinitely postponed.

Astronomy is necessarily a science of observation pure and simple, in which experiment can have no place except as an auxiliary. The vague accounts of striking celestial phenomena handed down by the priests and astrologers of antiquity were followed in the time of the Greeks by observations having, in form at least, a rude approach to precision, though nothing like the degree of precision that the astronomer of to-day would reach with the naked eye, aided by such instruments as he could fashion from the tools at the command of the ancients.

The rude observations commenced by the Babylonians were continued with gradually improving instruments—first by the Greeks and afterwards by the Arabs—but the results failed to afford any insight into the true relation of the earth to the heavens. What was most remarkable in this failure is that, to take a first step forward which would have led on to success, no more was necessary than a course of abstract thinking vastly easier than that required for working out the problems of geometry. That space is infinite is an unexpressed axiom, tacitly assumed by Euclid and his successors. Combining this with the most elementary consideration of the properties of the triangle, it would be seen that a body of any given size could be placed at such a distance in space as to appear to us like a point. Hence, a body as large as our earth, which was known to be a globe from the time that the ancient Phœnicians navigated the Mediterranean, if placed in the heavens at a sufficient distance, would look like a star. The obvious conclusion that the stars might be bodies like our globe, shining either by their own light or by that of the sun, would have been a first step to the understanding of the true system of the world.

There is historic evidence that this deduction did not wholly escape the Greek thinkers. It is true that the critical student will assign little weight to the current belief that the vague theory of Pythagoras—that fire was at the center of all things—implies a conception of the heliocentric theory of the solar system. But the testimony of Archimedes, confused though it is in form, leaves no serious doubt that Aristarchus of Samos not only propounded the view that the earth revolves both on its own axis and around the sun, but that he correctly removed the great stumbling-block in the way of this

theory by adding that the distance of the fixed stars was infinitely greater than the dimensions of the earth's orbit. Even the world of philosophy was not yet ready for this conception, and, so far from seeing the reasonableness of the explanation, we find Ptolemy arguing against the rotation of the earth on grounds which careful observations of the phenomena around him would have shown to be ill-founded.

Physical science, if we can apply that term to an unco-ordinated body of facts, was successfully cultivated from the earliest times. Something must have been known of the properties of metals, and the art of extracting them from their ores must have been practiced from the time that coins and medals were first stamped. The properties of the most common compounds were discovered by alchemists in their vain search for the philosopher's stone, but no actual progress worthy of the name rewarded the practitioners of the black art.

Perhaps the first approach to a correct method was that of Archimedes, who by much thinking worked out the law of the lever, reached the conception of the center of gravity, and demonstrated the first principles of hydrostatics. It is remarkable that he did not extend his researches into the phenomena of motion, whether spontaneous or produced by force. The stationary condition of the human intellect is most strikingly illustrated by the fact that not until the time of Leonardo was any substantial advance made on his discovery. To sum up in one sentence the most characteristic feature of ancient and mediæval science, we see a notable contrast between the precision of thought implied in the construction and demonstration of geometrical theorems and the vague indefinite character of the ideas of natural phenomena generally, a contrast which did not disappear until the foundations of modern science began to be laid.

We should miss the most essential point of the difference between mediæval and modern learning if we looked upon it as mainly a difference either in the precision or the amount of knowledge. The development of both of these qualities would, under any circumstances, have been slow and gradual, but sure. We can hardly suppose that any one generation, or even any one century, would have seen the complete substitution of exact for inexact ideas. Slowness of growth is as inevitable in the case of knowledge as in that of a growing organism. The most essential point of difference is one of those seemingly slight ones, the importance of which we are too apt to overlook. It was like the drop of blood in the wrong place, which some one has told us makes all the difference between a philosopher and a maniac. It was all the difference between a living tree and a dead one, between an inert mass and a growing organism. The transition of knowledge from the dead to the living form must, in any complete review of the subject, be looked upon as the really great

event of modern times. Before this event the intellect was bound down by a scholasticism which regarded knowledge as a rounded whole, the parts of which were written in books and carried in the minds of learned men. The student was taught from the beginning of his work to look upon authority as the foundation of his beliefs. The older the authority the greater the weight it carried. So effective was this teaching that it seems never to have occurred to individual men that they had all the opportunities ever enjoyed by Aristotle of discovering truth, with the added advantage of all his knowledge to begin with. Advanced as was the development of formal logic, that practical logic was wanting which could see that the last of a series of authorities, every one of which rested on those which preceded it, could never form a surer foundation for any doctrine than that supplied by its original propounder.

The result of this view of knowledge was, that although during the fifteen centuries following the death of the geometer of Syracuse great universities were founded at which generations of professors expounded all the learning of their time, neither professor nor student ever suspected what latent possibilities of good were concealed in the most familiar operations of nature. Everyone felt the wind blow, saw water boil, and heard the thunder crash, but never thought of investigating the forces here at play. Up to the middle of the fifteenth century the most acute observer could scarcely have seen the dawn of a new era.

In view of this state of things, it must be regarded as one of the most remarkable facts in evolutionary history that four or five men, whose mental constitution was either typical of the new order of things or who were powerful agents in bringing it about, were all born during the fifteenth century, four of them at least at so nearly the same time as to be contemporaries.

Leonardo da Vinci, whose artistic genius has charmed succeeding generations, was also the first practical engineer of his time, and the first man after Archimedes to make a substantial advance in developing the laws of motion. That the world was not prepared to make use of his scientific discoveries does not detract from the significance which must attach to the period of his birth.

Shortly after him was born the great navigator whose bold spirit was to make known a new world, thus giving to commercial enterprise that impetus which was so powerful an agent in bringing about a revolution in the thoughts of men.

The birth of Columbus was soon followed by that of Copernicus, the first after Aristarchus to demonstrate the true system of the world. In him more than in any of his contemporaries do we see the struggle between the old forms of thought and the new. It seems almost pathetic, and is certainly most suggestive of the general view

of knowledge taken at that time, that instead of claiming credit for bringing to light great truths before unknown he made a labored attempt to show that after all there was nothing really new in his system, which he claimed to date from Pythagoras and Philolaus. In this connection it is curious that he makes no mention of Aristarchus, who, I think, will be regarded by conservative historians as his only demonstrated predecessor. To the hold of the older ideas upon his mind we must attribute the fact that in constructing his system he took great pains to make as little change as possible in ancient conceptions.

Luther, the greatest thought stirrer of them all, practically of the same generation with Copernicus, Leonardo, and Columbus, does not come in as a scientific investigator, but as the great loosener of chains which had so fettered the intellect of men that they dared not think otherwise than as the authorities thought.

Almost coeval with the advent of these intellects was the invention of printing with movable type. Gutenberg was born during the first decade of the century, and his associates and others credited with the invention not many years afterwards. If we accept the principle on which I am basing my argument, that we should assign the first place to the birth of those psychic agencies which started men on new lines of thought, then surely was the fifteenth the wonderful century.

Let us not forget that, in assigning the actors then born to their places, we are not narrating history, but studying a special phase of evolution. It matters not for us that no university invited Leonardo to its halls, and that his science was valued by his contemporaries only as an adjunct to the art of engineering. The great fact still is that he was the first of mankind to propound laws of motion. It is not for anything in Luther's doctrines that he finds a place in our scheme. No matter for us whether they were sound or not. What he did toward the evolution of the scientific investigator was to show by his example that a man might question the best-established and most venerable authority and still live, still preserve his intellectual integrity, still command a hearing from nations and their rulers. It matters not for us whether Columbus ever knew that he had discovered a new continent. His work was to teach that neither hydra, chimera, nor abyss—neither divine injunction nor infernal machination—was in the way of men visiting every part of the globe, and that the problem of conquering the world reduced itself to one of sails and rigging, hull and compass. The better part of Copernicus was to direct man to a view point whence he should see that the heavens were of like matter with the earth. All this done, the acorn was planted from which the oak of our civilization should spring. The mad quest for gold which followed the discovery of Columbus, the questionings which absorbed the attention of the

learned, the indignation excited by the seeming vagaries of a Parcelsus, the fear and trembling lest the strange doctrine of Copernicus should undermine the faith of centuries, were all helps to the germination of the seed—stimuli to thought which urged it on to explore the new fields opened up to its occupation. This given, all that has since followed came out in regular order of development, and need be here considered only in those phases having a special relation to the purpose of our present meeting.

So slow was the growth at first that the sixteenth century may scarcely have recognized the inauguration of a new era. Torricelli and Benedetti were of the third generation after Leonardo, and Galileo, the first to make a substantial advance upon his theory, was born more than a century after him. Only two or three men appeared in a generation who, working alone, could make real progress in discovery, and even these could do little in leavening the minds of their fellow-men with the new ideas.

Up to the middle of the seventeenth century an agent which all experience since that time shows to be necessary to the most productive intellectual activity was wanting. This was the attrition of like minds, making suggestions to each other, criticising, comparing, and reasoning. This element was introduced by the organization of the Royal Society of London and the Academy of Sciences of Paris.

The members of these two bodies seem like ingenious youth suddenly thrown into a new world of interesting objects, the purposes and relations of which they had to discover. The novelty of the situation is strikingly shown in the questions which occupied the minds of the incipient investigators. One natural result of British maritime enterprise was that the aspirations of the Fellows of the Royal Society were not confined to any continent or hemisphere. Inquiries were sent all the way to Batavia to know "whether there be a hill in Sumatra which burneth continually and a fountain which runneth pure balsam." The astronomical precision with which it seemed possible that physiological operations might go on was evinced by the inquiry whether the Indians can so prepare that stupefying herb Datura that "they make it lie several days, months, years, according as they will, in a man's body without doing him any harm, and at the end kill him without missing an hour's time." Of this continent one of the inquiries was whether there be a tree in Mexico that yields water, wine, vinegar, milk, honey, wax, thread, and needles.

Among the problems before the Paris Academy of Sciences those of physiology and biology took a prominent place. The distillation of compounds had long been practiced, and the fact that the more spirituous elements of certain substances were thus separated naturally led to the question whether the essential essences of life might not be discoverable in the same way. In order that all might participate

in the experiments they were conducted in open session of the academy, thus guarding against the danger of any one member obtaining for his exclusive personal use a possible elixer of life. A wide range of the animal and vegetable kingdom, including cats, dogs, and birds of various species, were thus analyzed. The practice of dissection was introduced on a large scale. That of the cadaver of an elephant occupied several sessions, and was of such interest that the monarch himself was a spectator.

To the same epoch with the formation and first work of these two bodies belongs the invention of a mathematical method which in its importance to the advance of exact science may be classed with the invention of the alphabet in its relation to the progress of society at large. The use of algebraic symbols to represent quantities had its origin before the commencement of the new era, and gradually grew into a highly developed form during the first two centuries of that era. But this method could represent quantities only as fixed. It is true that the elasticity inherent in the use of such symbols permitted of their being applied to any and every quantity; yet, in any one application, the quantity was considered as fixed and definite. But most of the magnitudes of nature are in a state of continual variation; indeed, since all motion is variation, the latter is a universal characteristic of all phenomena. No serious advance could be made in the application of algebraic language to the expression of physical phenomena until it could be so extended as to express variation in quantities, as well as the quantities themselves. This extension, worked out independently by Newton and Leibnitz, may be classed as the most fruitful of conceptions in exact science. With it the way was opened for the unimpeded and continually accelerated progress of the two last centuries.

The feature of this period which has the closest relation to the purpose of our coming together is the seemingly unending subdivision of knowledge into specialties, many of which are becoming so minute and so isolated that they seem to have no interest for any but their few pursuers. Happily science itself has afforded a corrective for its own tendency in this direction. The careful thinker will see that in these seemingly diverging branches common elements and common principles are coming more and more to light. There is an increasing recognition of methods of research and of deduction which are common to large branches or to the whole of science. We are more and more recognizing the principle that progress in knowledge implies its reduction to more exact forms, and the expression of its ideas in language more or less mathematical. The problem before the organizers of this congress was, therefore, to bring the sciences together and seek for the unity which we believe underlies their infinite diversity.

The assembling of such a body as now fills this hall was scarcely possible in any preceding generation, and is made possible now only through the agency of science itself. It differs from all preceding international meetings by the universality of its scope, which aims to include the whole of knowledge. It is also unique in that none but leaders have been sought out as members. It is unique in that so many lands have delegated their choicest intellects to carry on its work. They come from the country to which our Republic is indebted for a third of its territory, including the ground on which we stand; from the land which has taught us that the most scholarly devotion to the languages and learning of the cloistered past is compatible with leadership in the practical application of modern science to the arts of life; from the island whose language and literature have found a new field and a vigorous growth in this region; from the last seat of the holy Roman Empire; from the country which, remembering a monarch who made an astronomical observation at the Greenwich Observatory, has enthroned science in one of the highest places in its government; from the peninsula so learned that we have invited one of its scholars to come and tell us of our own language; from the land which gave birth to Leonardo, Galileo, Torricelli, Columbus, Volta—what an array or immortal names!—from the little republic of glorious history which, breeding men rugged as its eternal snow peaks, has yet been the seat of scientific investigation since the day of the Bernoullis; from the land whose heroic dwellers did not hesitate to use the ocean itself to protect it against invaders, and which now makes us marvel at the amount of erudition compressed within its little area; from the nation across the Pacific, which by half a century of unequaled progress in the arts of life has made an important contribution to evolutionary science through demonstrating the falsity of the theory that the most ancient races are doomed to be left in the rear of the advancing age—in a word, from every great center of intellectual activity on the globe I see before me eminent representatives of that world advance in knowledge which we have met to celebrate. May we not confidently hope that the discussions of such an assemblage will prove pregnant of a future for science which shall outshine even its brilliant past?

Gentlemen and scholars all, you do not visit our shores to find great collections in which centuries of humanity have given expression on canvas and in marble to their hopes, fears, and aspirations. Nor do you expect institutions and buildings hoary with age. But as you feel the vigor latent in the fresh air of these expansive prairies, which has collected the products of human genius by which we are here surrounded, and, I may add, brought us together; as you study the institutions which we have founded for the benefit not only

of our own people, but of humanity at large; as you meet the men who, in the short space of one century, have transformed this valley from a savage wilderness into what it is to-day, then may you find compensation for the want of a past like yours by seeing with prophetic eye a future world power of which this region shall be the seat. If such is to be the outcome of the institutions which we are now building up, then may your present visit be a blessing both to your posterity and ours by making that power one for good to all mankind. Your deliberations will help to demonstrate to us and to the world at large that the reign of law must supplant that of brute force in the relations of the nations, just as it has supplanted it in the relations of individuals. You will help to show that the war which science is now waging against the sources of diseases, pain, and misery offers an even nobler field for the exercise of heroic qualities than can that of battle. We hope that when, after your all too fleeting sojourn in our midst, you return to your own shores you will long feel the influence of the new air you have breathed in an infusion of increased vigor in pursuing your varied labors. And if a new impetus is thus given to the great intellectual movement of the past century, resulting not only in promoting the unification of knowledge, but in widening its field through new combinations of effort on the part of its votaries, the projectors, organizers, and supporters of this Congress of Arts and Science will be justified of their labors.

METALS IN THE ATMOSPHERE.[a]

By Alfred Ditte,

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The earth's atmosphere contains an enormous quantity of dust, particles of which float in the air for varying periods of time. This dust is everywhere, in the fields as well as in town, and the only reason we do not see it continually is because the particles do not reflect enough light to make an impression on the retina. A ray of sunshine in a dark room reveals the presence of innumerable particles.

Any polished surface exposed to the air will soon be covered with an atmospheric sediment. All terrestrial substances, especially metals, may by mechanical action be reduced to a fine powder, light enough to be carried by the wind and held suspended in the air. The beating of the waves against the shore makes a powder, and the water in evaporating leaves a little saline residue in the air. One can imagine without much difficulty, but not without a certain disgust, the character of the dust particles found in city air; they form a means of contact between persons widely separated, and to this contact is due much of the disease common among great aggregations of people. Some of these innumerable corpuscles are bound to be germs of fermentations, of putrefactions, and of various alterations of the blood in epidemic diseases.

Not only are all these solid substances visible with sufficient light, but they may without great difficulty be collected for purposes of study. Pasteur was the first to devise a method of so doing by drawing the air through a tube containing a wad of nitrated cotton. When a sufficient quantity of air has been run through the air filter the cotton, with its deposit of dust, is treated with ether, which dissolves it, leaving a residue of dust particles. The insoluble bits of dust are collected by decantation, washed and dried, and then examined under a microscope.

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In this residue may be distinguished corpuscles of organic matter, with which we are not now concerned, and also mineral substances, which we will examine more particularly. Tiny as these bodies are, it is possible to measure them with a finely graduated micrometer, and it has been found that in diameter they ordinarily measure between one one-hundredth and one one-thousandth of a millimeter.

It is also possible to obtain an approximate idea of the quantity of these dust particles by drawing with an air pump a determined amount of air, bubble by bubble, through a tube containing a little pure water and then through a wad of nitrated cotton. The particles which have been retained by the water are secured by evaporation and united with those obtained by the dissolution in ether of the guncotton. By this method there have been found at Paris, during normal atmospheric conditions, from 6 to 8 mg. of dust to the cubic meter of air; after a day's rainfall, 6 mg.; after a drought of eight days, 23 mg. Naturally the quantity in country air is much smaller. These figures represent the total weight of all solid particles, mineral and organic; if the latter be eliminated by calcination in a current of air the cinders representing mineral matter will be found to vary from 66 to 75 per cent of the whole weight. In the residue are found cinders of salts soluble in water, of matter soluble in hydrochloric acid, and of substances which can not be dissolved either in water or in acid.

The particles floating in the air are held there only by atmospheric agitation, the most minute being held longest in suspense. It may well be asked how bodies of this kind, so much heavier than the air, can be held in the atmosphere. Circulation will show that grains of mineral as small as 0.01 mm. in diameter can nevertheless fall with considerable rapidity, 0.66 m. a second in the case of a gram of silica. It can easily be seen that a sphere of 2.5 density, 1 m. in diameter, would fall at a speed of 220 m. a second, if the fall were uniform and through air of ordinary density. The theoretical velocity of a corpuscle of d dimensions would therefore equal $\sqrt{220d}$. But in reality this is greatly modified in bodies of minute dimensions by the agitation and continual movement of the air, which fact accounts for the suspension of the atmospheric particles. They do, however, fall gradually, and are continually forming on the earth's surface a sediment that can easily be collected by stretching on a frame a sheet of paper treated with gelatin and placing the contrivance on an isolated roof 10 to 15 m. from the ground. Or a dust table, about a meter square, lined with thin sheet tin and turning on an axis so as always to face the wind, can be used with equal success. The wind passing over its surface constantly lets fall a portion of the dust it carries, and this deposit is afterwards collected with a flat hair brush. The quantity of dust varies with the velocity of the

wind and the humidity of the atmosphere, also with the season of the year and the state of the sun.

In Paris between 2 and 9 mg. of dust are collected on a square meter of surface in twenty-four hours. Taking 4 mg. as the mean, this corresponds to a daily deposition on a surface equal to that of the Champs de Mars (about 500,000 m^2) of 2 kilos (4.4 pounds) of corpuscles. An estimate made by forcing air through water and evaporating shows a weight of 6 to 23 mg. to a cubic meter of air. Taking in this case 6 mg. as the mean and considering a sheet of air, say, 5 m. in thickness, there would be almost 15 kilos (33 pounds) of dust in an area equal in extent to the Champs de Mars and a weight of several hundred kilos in air overhanging Paris. In the fields the quantity of dust collected is considerably smaller. It is hardly necessary to say that this sediment does not remain long in the place where it falls, but is quickly carried off again by the wind. However, the figures given will indicate in a slight measure the importance and extent of this aerial transportation of solid matter.

High buildings act as veritable dust traps. For instance, in a tower of Notre Dame Cathedral which no one had entered for several years, the wind, passing through the narrow windows 60 m. from the ground, had deposited a bed at least a millimeter in thickness of fine grayish dust. Analysis showed that this was of the same composition as the atmospheric dust, i. e., about 32 per cent organic matter and 67 per cent of cinders. Of this inorganic matter, 9 per cent was soluble in water, 24 per cent in hydrochloric acid, and the remaining 34 per cent consisted of a residue essentially silicate. Various analyses of dust accumulated in uninhabited portions of lofty structures showed very similar results; the dimensions of the particles were invariably compassed between 0.01 and 0.001 mm., and the cinders always represented about 75 per cent of all the matter collected.

Another method of investigating the solid bodies in the atmosphere is by making an analysis of meteoric water. Rain is always charged with a sediment collected in the air, which may be extracted by filtering and evaporation. It can be advantageously collected in a receptacle made of a series of porcelain plates, built up on three sides only and arranged on a frame like tiles on a roof. If this apparatus be of sufficient size considerable quantities of water will glide over the plaques and through a funnel into a large flask. Porcelain is much better than glass for this purpose, as the latter is likely to be attacked by the carbonic acid and ammonia in standing rain water.

The weight of the residue extracted from a liter of water varies considerably. At the observatory of St. Marie du Mont (Manche) the sediment obtained by evaporation of several liters of rain water

on June 1, 10, and 11, 1876, amounted to from 23 to 75 mg. per liter; at Paris it has run from 23 to 172, the maximum being 421 mg. This residue is blackish gray, except that collected in the fields, which is entirely white, and it invariably contains the same relative proportions of mineral substances and organic matter.

The size of snowflakes and the leisurely manner in which these little spongy masses fall through the air makes them even better fitted than rain drops to seize in their passage all the dust particles and solid bodies floating in the atmosphere. Moreover, solids are collected in the waters fused into the flake. Consequently, when Monsieur Tissandier collected with all proper precaution the first snows that fell on the towers of Notre Dame in the winter of 1875, he found in each liter of the snow water a body of corpuscles varying in weight from 56 to 118 mg. A liter of melted snow collected under the same conditions in the country contains from 48 to 104 mg. Furthermore, as one might suppose, the corpuscles are less numerous after a prolonged snowstorm, so much so that in Paris, after a heavy fall, only 16 to 24 mg were found. The residue obtained by the evaporation of melted snow is ordinarily an impalpable grayish powder, containing, at Paris, about 57 per cent of cinders, and in the country about 61 per cent.

Hail, because of its small size and its great density, does not collect the dust particles so easily. Nevertheless, it has been collected and examined in the same way.

Iron.—The examination of the cinders in the dust collected in these various ways enables us to recognize in our atmosphere the presence of a number of metals, the most important of which is iron.

When a strong magnet was held near some of the atmospheric sediment thus obtained, a portion of the corpuscles adhered to it and were brushed off for microscopic or chemical examinations. It was then discovered that these bits are made up essentially of iron. The same results were obtained with sediments collected in several very different localities. The examinations even went so far as to estimate approximately the quantity of iron contained in this magnetic residue by the intensity of the coloration of sulphocyanide of potassium in the dissolution of a known quantity of dust. These ferruginous particles were found to be either pure iron or that metal associated in certain proportions with other elements, such as nickel and phosphorus. M. Nordenskiöld, at Stockholm in 1871, examining the surface of the greatest fall of snow within the memory of man, found small quantities of metallic iron. But fearing this might have come from neighboring roofs, he had his brother examine the snow in a desolate plain surrounded by the forests of Finland. The black powder secured there was of the same character as that of Stockholm. The particles of iron drawn out by a magnet, when triturated in an agate mortar,

were recognized as forms of the metal exactly analogous to those found in the snow at Stockholm and other parts of Sweden. Furthermore, there was collected on the floating ice off Spitzbergen a gray powder containing little magnetic grains of iron coated with iron oxides.

In examining some carbonaceous dust collected in 1870 on the snow and ice of the Inlandis glacier, a sea of ice in Greenland, at 80° north latitude, there was found ferruginous corpuscles in which was determined the presence of nickel and cobalt. M. Jüng has verified these observations by his researches on the snows of Geneva. He noted the presence of iron in the storm of 1883 at Geneva, on the Salève, and on the Great St. Bernard Pass, at an altitude of 8,100 feet. On the surface of the great snow fields covering this lofty region he discovered a very fine blackish powder containing the characteristic globules and irregular fragments susceptible to the magnet. The evaporation of 15 liters of water from melting this snow gave M. Jung a residue formed of the same particles, which, treated with hydrochloric acid, made a solution with a strong iron reaction. The insignificant weight of the matter collected made it impossible for him to establish clearly the presence of nickel or cobalt. M. Nordenskiöld likewise observed some dust which fell at an altitude of 9,850 feet, near San Fernando, Chili, in November, 1883. The Cordilleras, which had been white with fresh snow, were covered in the space of half an hour with a sheet of red, composed principally of minute ferruginous particles, hard but slightly malleable.

In this powder, which did not contain metallic iron, were found reddish-brown globular grains soluble in hydrochloric acid and brownish-white grains insoluble in that acid and made up of a silicate-like feldspar. The first named was composed of oxide of iron, 74.60; oxide of nickel with traces of cobalt, 6.01; silica, 7.60; magnesia, 3.88; with small quantities of phosphoric acid, aluminum, chalk, and traces of copper. The richness of the material in iron, nickel, magnesia, and phosphoric acid is remarkable. In contrast to this discovery, M. Tissandier, experimenting with rain waters collected at St. Marie du Mont (Manche), was able to obtain 124 milligrams of corpuscles susceptible to magnetic influence, which, under the action of hydrochloric acid, left only an insignificant residue of sillica, and found a solution in which ammonia precipitated an abundance of iron oxide, sulphocyanide of potassium gave an intense clear color, and even the yellow prussiate of potash a deposit of Prussian blue. The liquor separated from the iron gave with ammonium sulphide a light-black precipitate of sulphide of nickel, forming with borax lead its characteristic pearl-violet color and turning to a brownish gray on cooling. M. Jung also collected snow at different altitudes—at 1,225 feet at Montreux on the border of Lake Geneva; 3,300 feet at the

station des Avants below the Moutiers; at 8,100 feet at the hospice of the Great St. Bernard—and compared the evaporation residue from this snow with the dust collected in the towers of several cathedrals at Paris, Geneva, Lausanne, Varsovie, and at Samara on the Volga. He concluded that iron is as surely present in recent snows as in the dust of centuries accumulated in the clock towers of the old churches. In all cases the appearance of this metal indicated that it had been subjected to high temperatures.

These corpuscles, found always in greater quantities in the snows of lower altitudes than from higher regions, do not always have the same characteristics, and students of them have classified them into several groups:

1. Irregular amorphous grayish fragments, measuring from 0.1 to 0.2 mm. in diameter.
2. Mammilated particles, black and opaque, much smaller, measuring only 0.01 to 0.05 mm.
3. Fibrous particles of about the same size.
4. Spherical corpuscles, black and opaque, diameter 0.01 to 0.02 mm.
5. Corpuscles apparently with a tiny vase-like neck.

Moreover, these minute ferruginous corpuscles divide into two classes, some which have been deposited on the surface of the earth, others of an extra-terrestrial origin. The effects of showers of meteors are shown in an incontestable manner. Ehrenberg, Arago, Quetelet, Daubrée, and Nordenskiöld have brought forward a great number of facts in this connection. Examining a fine dust which on the 25th of January, 1859, fell in the Indian Ocean, covering the decks of the good ship *Josiah Bates*, Ehrenberg showed that this powder, which to the naked eye appeared to be only little agglomerate grains, was in reality formed by drops composed of metallic iron and iron oxide solidified and creased in a manner analogous to that of the Batavian tears. He considered this proof that a mass of meteoric iron is made incandescent by the friction of the air. Sediments of this sort may come from the superficial fusion of meteorites, or, as Daubrée has indicated in his memoir on the meteorite of Orgueil,[a] they may be simply the result of disintegration.

The dust is so friable that some bits were reduced to a powder by the pressure of the fingers. Its different parts are cemented together with some alkaline salts so soluble in water that this liquid will work a complete disintegration into a fine powder that will pass through the hardest filters. Numerous cases of rains of fire which should apparently be attributed to the fall of incandescent débris of meteorites are familiar. The Baron de Reichenbach insisted strongly

[a] Journal des Savants, 1870.

on a granular formation of meteorites, which can exist as well as an impalpable powder floating in space as in the forms of conglomerates of several hundred kilos weight. Very small grains which, in passing through the atmosphere, were heated, melted, and volatilized, appear to us in the form of shooting stars; it is supposed that matter, not over a gram in weight, is sufficient to produce one of these meteors. Searching for the dust of shooting stars, de Reichenbach found, in 1864, on the summit of mountains of Germany some ferruginous dust giving nickel and cobalt reactions. On the hill of Labisberg, at an altitude of 1,300 feet, under the shelter of the beech forests, untouched by ax or pick, he found similar traces of nickel and cobalt. Again, in a note of March 4, 1812, Von Baumhaver published some observations on magnetic particles obtained from hailstones, citing particularly a hail storm he observed at Padúa on the 26th of August, 1834. After this meteoric period of August and September Phipson managed to collect some black angular particles which were neither carbonaceous nor coated with soot, and which, dissolved in hydrochloric acid, formed a perchloride of iron. Nordenskiöld encountered in the snow collected on icebergs some metallic particles about a quarter of a millimeter in circumference containing metallic iron coated with carbonized oxide and was at the same time able to determine the presence of nickel and phosphorus.

After a heavy fall of snow at Geneva on October 5, 1883, M. Jung melted a quantity collected on the Salève, and found therein a deposit of powder exceptionally rich in iron globules.

There fell in 1883, about the annual period in November characterized by an abundance of shooting stars, a rain remarkably strong in metallic dust of cosmic origin. These particularly abundant globules of iron might have been produced by the breaking up of much larger meteorites into microscopical shooting stars. From his Stockholm analysis of snow, in which, as in hail, he found bits of iron, Nordenskiöld satisfied himself that hail is condensed around minute grains of cosmic matter floating in the air and falling imperceptibly but continuously to the earth. He regards the existence of such material as proven by his observations and attributes to its fall a considerable importance not only from the standpoint of the geologist and physiographist, but from that of the farmer; this last on account of its phosphorus, which with nickel and cobalt is characteristic of meteoric iron. To cite a single example: An analysis of the meteoric iron found at Santa Catarina, Brazil, gave the following components: Iron, 63.69 per cent; nickel, 33.97 per cent; cobalt, 1.48; with small quantities of phosphorus, sulphur, carbon, and silica. This iron, remarkable for its exceptional quan-

tity of nickel, is not attacked by the action of air and water, and is recognizable by its smooth gray tint.

Nordenskiöld concluded from all these facts that a considerable number of aërolites constantly enter our atmosphere and are there broken up, thus giving an extraterrestrial origin to the magnetic corpuscles of the air.

The little meteoric particles do not, however, always appear in the form of polished spheres, nor in the characteristic globules. The iron floating in our atmosphere often appears in irregular black fragments formed by a conjunction of extremely minute granules grouped in compact masses sometimes with a rough and irregular surface.

The study of hailstones has led to the same conclusions as that of snow. In a hailstorm at Stockholm, Nordenskiöld found some black grains which when ground in an agate mortar produced bits of metallic iron. In another case the hailstones had a metallic nucleus in their center. Everman demonstrated the presence of octahedrons of iron sulphate in some hail from the Prussian province of Orembourg, and Pictet recognized the presence of iron in the nucleus of hailstones which fell in the Majo Province of Spain. Hail collected at Padua in 1834 contained magnetic grains of both iron and nickel, a circumstance which connects them with the aerolites, since a combination of iron and nickel is a characteristic constituent of meteoric iron.

The apparent planetary origin of these aerial magnetic particles may best be verified by a comparison with filings from the surface of actual aerolites. Experiment has shown that the powder thus obtained and the corpuscles collected in the atmosphere are very similar. The fragments filed from the black crust adhering to the metal have the form of irregular little coated spheres. The cosmic particles obtained by Nordenskiöld showed a striking resemblance to those extracted with a magnet from the sediment of French rain.

All these observations establish the fact that much of the ferruginous dust found in the atmosphere comes from meteorites. These metallic masses hurtling through space are broken into fragments, throwing off incandescent particles of metallic iron. The lightest of this débris is carried through the air by atmospheric currents and falls to the earth in the form of magnetic oxide of iron, more or less completely fused. The luminous train of shooting stars is due to combustion of these innumerable particles, resembling somewhat the sparks thrown off by an iron ribbon burning in oxygen. Meteorites, as everyone has noticed, often have luminous trains, which are to be attributed to the incandescent débris detached from the mass.

Thus it appears that ferruginous powder of extraterrestrial origin is falling constantly to the earth and that a part of the atmospheric dust comes from planetary space. As Daubrée has brought out in

his observations on the meteorite of Orgueil, some of these particles come from the explosion of meteorites or from their simple disunion when friable and prone to disintegration. Assuming that their mean diameter is a constant of 0.01 mm., which, in fact, is a rather too liberal estimate, it would take 2,500 of them to cover a square millimeter and 250,000 to equal in bulk a cubic millimeter. Therefore it is easily appreciated that the deposit of iron on the earth's surface from this source even in a considerable interval of time will not be great.

But, admitting that some of the iron dust is of extraterrestrial origin, it is equally true that a large part of it is swept from the earth's surface by the wind or carried up in the smoke of the foundries. In the neighborhood of these works may be collected globules of magnetic iron oxide, which, rising as sparks, took the globular form in cooling. It is easily shown that bits of iron at high temperatures become spherical, and that a mass of it combining at red heat with oxygen will divide into microscopic globular fragments. When very fine iron filings are made incandescent by passing through a hydrogen flame, they burn brilliantly. Tissandier has discovered, by collecting the products of this combustion on a porcelain plate and examining them with a microscope, that they are in the form of spherical globules, vase-necked spheres, irregular surfaced, or fibrous fragments incompletely fused. Powder obtained by striking a piece of iron with a flint is made up of the same kind of globules. An iron wire burning in oxygen will form globules of magnetic oxide visible to the naked eye and at the same time others much smaller, which may be collected in water at the bottom of the flask. These are visible only under great magnification, since their diameter rarely exceeds 0.01 of a millimeter.

The combustion of coal in factories furnishes the air an abundance of iron oxide from the decomposition of ferruginous pyrites contained in the coal. But all these particles obtained in the various ways mentioned, whether from the combustion of iron, coal, or other substances, are easily distinguishable from those of cosmic origin by the fact that they never contain nickel in any form.

Tilled land and salt water, whence gusts of wind snatch up particles the more minute of which measure scarcely 0.001 mm., often contains magnetic dusts in comparative abundance. A magnet passed over their surface attracts tiny grains of magnetic iron oxide. This is entirely independent of the particles due to the continual destruction of enormous quantities of iron in manufacturing. The dust from pulverized magnetic iron ore and other ferruginous minerals, or the dust formed by oxidation in open air or from fresh or salt water, never occurs in the mammilated, fibrous, or spherical forms. There are amorphic grayish powders which do not resemble those of planetary origin and are very different from those produced at

high temperatures. Iron is also found in semitransparent masses, green, yellow, or pink, mixed with opaque black particles. These M. Stanislas Meunier believes to have come from the débris of serpentine minerals—diorite, amphibolite, serpentine—containing granules of magnetite and always rich in oxidized iron.

But this terrestrial source of ferruginous dusts can not explain the extraordinary abundance of microscopic particles of iron found in polar and alpine snows and in rains collected in open country. The presence of this nickel-bearing iron dust can be explained only as a powder obtained from the surface of meteorites in the ways we have shown.

Metals other than iron.—It follows, then, that iron is the metal most abundant in the air, and that in every case when its origin is extraterrestrial it is associated in variable proportions with nickel and cobalt; but there are also other metals in the atmosphere. The analysis of their cinders, as already mentioned, shows that they are composed of some substances soluble in water, others soluble in hydrochloric acid, and some insoluble. The almost white sediments collected in the fields contain about 40 per cent of salts soluble in water, 30 per cent of such matter as calcium and magnesium carbonates, oxide of iron, and some insoluble substances like silica and clay, with small quantities of carbon.

An examination of the dust deposited in the towers of Notre Dame gave 67 per cent mineral matter, 9 per cent of which was soluble in water, 23 per cent soluble in hydrochloric acid (this decomposing into 6.1 per cent sesquioxide of iron, 16 per cent calcium carbonate, and 2.1 per cent magnesium carbonate, with traces of aluminum and phosphorus), and 34.3 per cent of matter, principally silica, not soluble in the acids. A grayish powder, fine and soft as meal, collected at Boulogne on October 9, 1876, contained in a dry state, besides 9.7 per cent of organic substances, 55 per cent of silica, 1.8 per cent aluminum (with traces of iron), 30.6 per cent calcium carbonate, and 2.5 per cent magnesium carbonate. In the ash calcium, aluminum, magnesium, and other metals were also found.

Besides their two principal components—iron and nickel—meteorites and their débris contain small variable quantities of cobalt, manganese, chrome, tin, magnesium, and aluminum. Some minerals in particular are contained in these bodies: Schreibersite (phosphide of iron and nickel), magnetite and chrome iron, which is sometimes found in considerable quantities in the form of tiny grains, and minute crystals, together with olivine and other silicates. In short, meteorites may be arranged in a long series, at one extremity of which are those composed chiefly of iron and nickel and at the other chiefly nonmetallic mineral substances, as olivine, enstatite, feldspar, amphi-

bole, pyroxene, variously associated. All of the meteoric minerals can be found in the dusts of the atmosphere.

Meteors may fall in a direction opposite to that of the earth's movement, in which case their relative speed, being the sum of the two movements, will be very great, perhaps 70 km. a second. The resistance of the air to a flight of such speed produces enough heat to completely burn and volatilize the matter. If, on the contrary, the movement of the falling mass is in the same direction as that of the earth, its relative velocity—the difference between the two absolute speeds—is scarcely 16 km. a second. In this case the heat developed is sufficient only to fuse the mass and vitrify its surface, then perhaps to break it in such a way as to form a meteorite or aerolite. It is not sufficient to make a shooting star with its great train of fiery particles. Consequently, in coming into the earth's atmosphere, aerolites, whether big or little, encounter a friction that generates heat and incandescence, consequently combustion, fusion, volatilization; condensation of the volatilized particles follows, and the dissemination of these condensed particles. Thus it is easy to understand how meteorites bring into the atmosphere various metals, free or in combination, and why metalliferous minerals, in corpuscles so minute that it is impossible to separate and identify them, may be found in the air entirely independent of the pulverized minerals raised from the earth's surface.

Matter soluble in water.—As already mentioned, the "cinders" of atmospheric sediments, when treated with water, always yield a certain amount of soluble salts. These are chlorates, alkaline sulphates, or calcium sulphate, and nitrates, particularly that of ammonium.

Ammonium nitrate.—A drop of rain allowed to evaporate spontaneously on a bit of glass leaves crystals of various shapes on its borders as the corpuscles are drawn toward the center. A star with six points is well marked when the crystallization has taken place slowly; more rarely the crystals assume the plumule form. Ammonium nitrate frequently forms remarkable groups of crystals in the shape of crosses and swords, like those obtained by evaporating a drop of snow water. In no other manner can similar crystals be obtained, neither by varying the solution of the salts nor the method of evaporation. It will form only in regular crystals ramifying uniformly from a common stem or else in isolated prisms. Tissandier attributes this peculiar crystallization in meteoric water to some organic matter dissolved in the rain or snow. The evaporation of this water leaves in the bottom of the vessel a hard, fragile residue somewhat similar in appearance to coagulated albumen. Crystals of ammonium nitrate are easily recognized by their solubility in alcohol and by the fact that heat decomposes them without residue. Their presence in the air can not be verified, since, as everyone knows, nitric acid and ammonia unite readily to form ammonium nitrate.

Sulphate of soda.—Sulphate of soda is frequently found in the matter soluble in water, and it crystallizes in four-sided prisms, like those formed by a supersaturated solution of that salt. It is only necessary to introduce into one of these solutions a few flakes of snow to determine immediately its crystallization. Monsieur Goernez has shown that deposits from the most widely varied locations have this same property. Its presence in the air, however, is determined with less certainty than that of the more widely prevalent ammonium nitrate, and the atmospheric deposits show in every case the crystallization of a supersaturated solution of that nitrate. Not only has Monsieur Goernez demonstrated that flakes of snow or solid atmospheric sediments will determine the crystallization of supersaturated solutions of soda sulphate, but that almost all bodies exposed to the air will do the same, showing that all these bodies contain traces of soda sulphate, somewhat difficult to detect by chemical processes, but made apparent by using supersaturated solutions of that salt as reagents.

The prevalence of soda sulphate is everywhere demonstrated, and since that salt exists in water, mineral, river, or sea, it is naturally found in the soil. Having a tendency to crystallize in a finely divided state on the surface of a porous body, the least wind will carry it off and deposit it elsewhere. Simple evaporation of waters containing sulphate of soda may perhaps account for its presence in the atmosphere. The same is true of any soluble body contained in water; the salt thus dissolved may be carried off by evaporation and be distributed in small quantities in the surrounding atmosphere. This has been proven in the case of perchloride of iron by evaporating a solution thereof above the boiling point of the liquid.

Still other causes favor the presence of sulphate of soda in the air. Sulphurous gas, sulphuretted hydrogen produced in the atmosphere, is there easily transformed into sulphuric acid and on coming into contact with salt from the ocean produces a sulphate of soda. Again, the carbonate of soda in the presence of calcium sulphate, and numerous other sulphates as well, will give a soda sulphate and some carbonates. So it is established that sulphate of soda is formed in various ways and that in a humid porous body it crystallizes so minutely that the least puff of wind will scatter it everywhere. Whatever may be the origin of sulphate of soda, which is in the earth and water, it is apparent that sodium in that form is one of the commonest elements in the atmosphere.

Sea salt.—Sea salt, which will crystallize in cubes on the evaporation of meteoric water, is also found in the air. Its presence was determined in melted snow collected on the lofty tower of Notre Dame in December, 1874. But residual dusts from melted rain and snow have no action on the supersaturated solutions of acetate, borate, hyposul-

phate, or soda sulphate, which shows that these substances, although efflorsecent, are only accidental in the atmosphere. The same is true of nitrate of lime and calcium chloride, which are readily given up to the air, although their sources are not to be found in the atmosphere.

Accidental substances.—Besides the dusts which the normal air almost always contains, there are those more exceptional ones of volcanic origin. Such was a dust which fell with the snow in Norway on March 29–30, 1878; it was gray and fibrous, formed of grains of 0.02 to 0.03 mm. diameter. These were characteristic fragments of pumice and little grains of iron oxide in octahedron cuboids. There are numerous examples of the transportation for great distances of dusts, volcanic cinders, and ashes from great fires. For instance, the sand that fell on the western Canaries on the 7th of February, 1863, came in all probability from the Sahara, more than 200 miles. More recently the cinders from the great Chicago fire arrived at the Azores some forty days after the beginning of the catastrophe. The celebrated dry fog, which in 1783 covered all Europe for three months, first appeared at Copenhagen, where it continued one hundred and twenty-six days. It was caused by an eruption in Iceland. In September, 1845, a phenomenon of the same sort but less formidable was observed on the Shetland and Orkney Islands. This came from an eruption of Hecla on September 2, and the cinders had traveled more than 500 miles. The atoms that fell during the cyclone of 1879 in the vicinity of Naples and Palermo were tinged with yellow. In that region also have been found black spheres and globules, susceptible to the magnet, the diameters of which at Palermo were between 0.004 and 0.028 mm.; at Naples 0.007 to 0.020 mm., and from 0.011 to 0.040 mm. at Teramo. These measurements agree well with those magnetic spherules following on the coasts of Algeria and Tunis.

A shower of cinders fell in the vicinity of Etna from the 24th to the 29th of May, 1886; examined in the observatory of Palermo, they showed the little laminated crystals characteristic of the ejections of Etna. Similar phenomenon have been observed after the eruption of Krakatao.

Conclusion.—Leaving aside the dusts which are temporarily brought into the atmosphere by volcanic eruptions or other accidents, we see that the air ordinarily contains only a small number of metals—sodium, calcium, magnesium, aluminum, and more especially nickel, cobalt, and iron. These have all a terrestrial origin, except the last three, which come from out of planetary space. The proportion of solid matter in the air does not appear great enough to be of significance in the physiography of the earth, but almost a third of it is composed of organic matter containing living germs. This part at least concerns the biologist and assumes some importance from its pathological consequences.

OBSERVATIONS ON VISION IN BRIGHTNESS AND IN OBSCURITY, WITH A HYPOTHESIS ON THE CAUSE OF COLOR-BLINDNESS.[a]

By O. Lummer.

A. Theory of J. v. Kries.[b]

It has long been known that the retinal layer of rods and cones constitutes a structure sensitive to light by means of which energetic impulses from without excite the optic nerve. While investigations concerning acuity of vision appear to warrant the conclusion that the cones alone suffice for sight, yet the anatomical structure of the rods, closely resembling as it does that of the cones, indicates that they, too, play a part in seeing. Recent physiological researches on vision under feeble illumination and on the influence of the visual purple in the rods upon the perception of color have rendered it more and more possible to distinguish between the parts played by these two kinds of retinal organs.[c]

As a basis for the investigation we take the theory of Von Kries, which holds that the cones are a color-perceiving "brightness apparatus," the rods a color-blind "darkness apparatus." According to this theory the cones are adapted for vision under high illumination, and their excitation by light waves produces in the brain the sensation of color, while the rods with their visual purple are insensitive to color, become active only in dim light, and are able to much increase their sensitiveness in the dark. Von Kries calls this peculiarity of the rods "adaption to obscurity" [Dunkeladaptation]. Before the cones react to color the rods convey to the brain the impression of colorless light.

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[a] Translated by permission from Verhandlungen der Deutschen Physikalischen Gesellschaft, Brunswick, VI: 2, 1904.

[b] J. v. Kries. Uber die Funktion der Netzhautstäbchen. Z. S. f. Psych. u. Phys. d. Sinnesrogane, 9, 81–123, 1894.

[c] See A. König, Über den Menschlichen Sehpurpur und seine Bedeutung beim Sehen. Sitzber. d. Berl. Akad. d. Wissensch., p. 577, 1894.

We learn from the anatomy of the retina that in the fovea centralis and a portion of the macula lutea cones only are found, rods being entirely wanting, while on the remaining portion of the retina there are both rods and cones, arranged, indeed, in such a manner that toward the periphery the rods outumber the cones. We know, too, that the fovea centralis is the special spot used when the eyes are fixed upon an object and focused for direct vision. In fixed or direct vision (foveal or central vision) the rods therefore take no part; in indirect (peripheral or oblique) vision the rods as well as the cones are employed. Thus in feeble illumination the two visual organs enter into sharp competition, and when the light becomes sufficiently dim the advantage lies with the color-blind rods, so that everything then appears gray on a gray background—that is, in colorless light.

B. Recent Anatomical Discoveries Relating to Vision.

Recent investigations of the retina[a] show that very frequently several rods are attached to a common nerve fiber, while the cones—at least those of the fovea centralis—have each a special central connection. This enables us to partially understand why the stimulation of the rods is felt before that of the cones, especially as they are affected by all light waves while the cones differentiate the waves according to length. It is estimated that we have in all 113,000,000 rods and 7,000,000 cones (of which only 4,000 are in the fovea centralis and 8,000 to 13,000 in the macula lutea), whereas connected to them all there are only 1,000,000 nerve fibers, which, though interlaced in a bundle like a cable, separately convey to the brain the excitations of light.

Besides this there is, corresponding to the mosaic of the rods and cones of the retina, an equally regular mosaic of ganglion cells in the cortex of the occipital lobe of the brain, in the particular lobule known as the "cuneus," where Munk has located the "Sehsphäre," or center for cortical vision. The retinal elements may therefore be likened to the keys of a piano, by whose means, through the agency of the conducting nerve fibers, the strings in the visual center are set in vibration. Yet the path from the retinal elements to the cuneus is not a direct one, but is several times interrupted. For example, in the anterior pair of corpora quadrigemina the incoming nerve fibers break up into many ramifications, while the path leading thence onward to the cortex begins there with similar ramifications. The finest branchlets are not, however, so connected as to allow direct

[a] See R. Greeff, The microscopic anatomy of the visual nerve and the retina. From the Handbuch der Augenheilkunde of Graefe and Sämisch 2, Aufl. 1 (5), Berlin, 1901.

conduction (contact theory). While the function of these contact stations has been compared to that of an electrical interruptor, I am inclined to think that there is here inserted in the conducting path a potential capacity which increases the self-induction due to the propagation of the electro-magnetic light waves, in reverse of the process of Pupin for telephoning over great distances by means of cables.

C. Experiments on Vision in Brightness and Obscurity.

In order to illustrate the functions of the rods and cones and their competition, the following experiments are introduced:

I. DEVELOPMENT OF THE SPECTRUM BY GRADUAL HEATING OF AN INCANDESCENT LAMP.

An incandescent lamp with large filament is placed in a suitable box, and means are provided for gradually varying the heating current between the limits corresponding to dull-red glow and incandescence. The filament serves as the source of light and a large spectrum is thrown on a white screen by means of a Rowland concave grating. After the eye has become accustomed to complete darkness the current is increased until the first appearance of light is recognized on the screen. This first recognizable light is colorless, and makes the impression of "rod-white" luminosity. As the current is increased the intensity of the colorless light waxes and appears to stretch farther toward both ends of the spectrum, and sensations of color are gradually associated with those of light. After color begins to appear the interesting observation is made that the position of apparent maximum intensity, lying first in the blue green, is displaced more and more toward the yellow green of the spectrum. This displacement may be confirmed by marking the brightest spot and then letting the lamp gradually wane in intensity till only gray-white luminosity remains. The spot where this is seen brightest is then marked, and the light is increased till both marks are seen.

From this experiment it follows that the rods first perceive light, and that their greatest sensitiveness is for the blue-green region of spectrum, while the cones are most sensitive to yellow green. The experiment is founded on the researches of Draper[a] and H. F. Weber.[b]

II. EXPERIMENT WITH GLOWING PLATINUM FOIL.

In order to show the competition between the rods and cones a large strip of platinum foil is gradually heated by an electric current from a dull reddish luminosity to a bright-red glow. Observed

[a] Draper, Amer. Jour. Sci. (2) 4, 1847; Phil. Mag. (3) 30, May, 1847; Scient. Memoirs, p. 33, London, 1878.

[b] H. F. Weber, Berl. Akad. Ber., 1887, p. 491; Wied. Ann. 32, 256, 1887.

directly the foil appears always red and sharply defined; but observed obliquely it appears brighter, loses its color and takes on a whitish brilliance, at the same time losing sharpness of contour. These apparent changes of color and brightness can be noticed even at a bright-red glow.

III. EXPERIMENT WITH THREE GLOWLAMPS HAVING LARGE FILAMENTS ("GRAY GLOW" AND "RED GLOW").[a]

(*a*) The competition between the two organs of sight is yet more obvious when several parallel glowlamps with large filaments are set up at a distance of 1 to 1½ m. apart and provided with means for gradually decreasing the electric current. As long as the brightness of the lamps is so feeble that the rods assist in observing them, only the one directly observed appears red, while the others seem to have a colorless, magical, rod-white luminosity. However quickly the eye passes from one lamp to another, only that directly observed at the instant is red—the others at once change to white.

(*b*) In order to show that the "gray glow" is perceived before the "red glow" appears, the current is entirely cut off. Then the lamps fade slowly (owing to their thick filaments) and the directly observed lamp, which is red, disappears, while the others, seen obliquely, still present a white luminosity. By turning the current off and on this observation may be repeated as many times as one pleases, and the thicker the filaments the more successful the experiment. For a lecture experiment the distance of the lamps would naturally be greater.

IV. EXPERIMENT WITH A VERY SMALL BLUE FLAME.

Observe directly and then obliquely a blue gas flame from an easily regulated burner with a small orifice. As observed directly the flame appears sharply defined and of a blue color, but with indirect vision its appearance changes to a disk of some size having the appearance of moonlight and surrounded by a feebly luminous zone.

V. COLORLESS APPEARANCE OF THE SPECTRUM WHEN THE ILLUMINATION IS FEEBLE.

A pure spectrum of an arc light is produced, and its intensity gradually diminished by means of two Nicol prisms. The red and blue colors are the first to disappear, then the yellow, and finally there remains in place of the bright-colored spectrum a colorless, dull spectrum, which when viewed obliquely takes on a rod-white luminosity over its whole length.

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[a] O. Lummer, Verh. d. D. Phys. Ges. 16, 121–127, 1897; Wied. Ann. 62, 14–29, 1897.

(The writer connects with this phenomenon, which was first observed by Von Bezold and later more exactly investigated by Hering and Hillebrand, the origin of the theories of König and Von Kries.)

VI. THE PURKINJE PHENOMENON WITH LARGE AND SMALL FIELDS.

(*a*) *Large fields.*—A projection apparatus with two large Nicol prisms is suitable for the demonstration of the Purkinje phenomenon. For this purpose the slit is replaced by a round opening, and an enlarged image is thrown upon the various colored fields to be compared. These are preferably of colored paper, from which four arcs are combined to form a large field. Red and blue-green are suitable colors and are to be so chosen that with the strongest available lighting the red is perceived to be more bright than the blue-green. In case suitable papers are not available, the same effect can be reached by interposing in the beam suitably colored glasses or stained gelatin films. If the brightness of the light is gradually diminished, the blue-green becomes at length brighter than the red, and finally the red disappears, while the blue-green changes to the colorless "rod-white."

(*b*) *Observation of small fields.*—The large field just described is covered with black paper or velvet, except in two small spots, where the colored paper may be seen. Now, however much the intensity of the light is diminished, the red always appears brighter than the blue-green, provided both spots are observed directly so that their images fall on the fovea centralis or macula lutea, and not toward the periphery of the retina where both rods and cones are present.

(*c*) *Alternate observation of the large and small fields.*—In order to make the competition of the rods and cones still more striking, the two fields may be observed alternately. Having reduced the intensity of the light on the small field, all the while recognizing the red to be brighter than the blue-green, the screen is removed and the eye sees, again, suddenly, the large field. The blue-green parts now appear colorless, but of a magical brightness, while the red parts become almost black.

The Purkinje phenomenon may be observed in ordinary conditions, as when a picture gallery is visited on a very cloudy day or in the twilight, for then all the red tints appear dark and obscure, and all the blue ones colorless and whitish.[a]

Helmholtz also mentions that of all objects the blue sky appeared to retain color longest at twilight, and I believe I am right in assuming that the moonlit landscape is "rod-white," for at least the silver luster of moonlight is very similar to the ghostly gray-white of the rods.

[a] H. v. Helmholtz: Handbuch der Physiol. Optik. 2 ed. p. 429. (Leopold Voss, Leipzig, 1896.)

VII. OCULAR PHANTOMS.

The hallucinations of rod vision are best illustrated when a small surface is observed whose retinal image does not exceed the area of most distinct vision and whose gradual increase of brightness can be noted, beginning with darkness. I employ the following apparatus: An electrical glow lamp of 65-volt type is placed in a box with a single aperture 15 mm. in diameter, and connected to a 110-volt circuit whose current may be gradually varied from zero upward. Behind the opening is placed a dark shutter, and in front of this a movable brass diaphragm with different holes of 3, 6, and 9 mm. diameters. An enlarged, distinct image of the sharply bounded aperture is then cast on a white screen, and there are placed in the path of the beam several sheets of gelatin stained blue-green, so that the rods are more strongly impressed than the cones.

So long as the brightness is so feeble that the cones are excluded, the light spot, seen obliquely, appears colorless and lacking sharp outlines; but it quite disappears when gazed at fixedly. This disappearance occurs even when the light spot is so large that its image covers the whole of the macula lutea, as shown by the introduction of the larger diaphragm. To be sure, the disappearance is more difficult to produce, because the slightest movement of the eyes then renders the spot visible, and the wandering eye involuntarily takes the position where it receives the most light. Hence it happens that the spot floats in and out of the vision, for as soon as we attempt to fix distinctly what we saw indirectly the "ghost" disappears.[a] But when the light is made so bright that the cones are impressed this condition of things ceases, and we see the light spot distinctly and at rest with its sharp outlines and its blue-green color. The experiment is less successful when performed with red stained gelatin, but even in this case the spot may be caused to disappear by proper reduction of the illumination, as in Experiment III, where the dark-red glowing lamp filament becomes invisible by direct vision, while yielding the gray-glow appearance with oblique vision.

D. Experiments with Bright Spectra.

[Hypothesis as to the cause of color-blindness.]

Discrimination between the rods and cones and acquaintance with their different functions has not yet furnished the answer to the question why the cones differentiate colors, or what means they employ, and why the rods grow more sensitive in obscurity. It is true that the cones are destitute of the visual purple, so that perhaps this plays a part in "adaptation to obscurity."

[a] See O. Lummer, Beitrag zur Klärung der neuesten Versuche von R. Blondlot über die n-rays. Verh. der Deutschen Phys. Gesellschaft, 5, 418, 1903.

But what anatomical peculiarity have the cones which enables them to distinguish red from blue? For it seems clear that this distinction is made in the retina and not in the brain.

It is a fact that in the eyes of birds, which, moreover, have many more cones than rods over the whole extent of the retina, all the cones have color-differentiating organs; oil cells colored red, yellow, blue, and green. But these oil cells are found only in the cones of birds and certain amphibious animals and reptiles, not at all in man. And yet our cones have a special structure different from the rods, for the outer members show a series of plane parallel plates whose distance apart Max Schultze estimates to be in conformity with the wave lengths of light. May not these plates serve to differentiate the light as in Lippman's method of color photography? Against this view, which I find was propounded a long time ago by W. Zenker[a] and Max Schultze, and then again apparently forgotten, there is the objection that the rods also in "hardening" show a distinct platelike separation. But before using the fact to oppose the hypothesis above mentioned, it must be proved that the rods showing this platelike separation are not from the edge of the macula lutea. I am inclined to believe that the rods which border upon the macula lutea tend to approach a more conelike type than the others.

However this may be, the phenomenon of total color blindness or lack of all color perception can scarcely be satisfactorily explained by the Young-Helmholtz or the Hering theories, which assume that the visual substances are either fused into one or partly absent. Admitting, however, that the distinction of colors belongs to the cones and colorless vision to the rods, it is easy on the other hand to explain total color-blindness by the hypothesis that in such cases the cones are absent. This explanation was advanced by H. König and supported by the fact that all animals which live in darkness (the bat, mole, hedgehog, nocturnal monkey, and others) have no cones. These animals have been designated by Max Schultze as "rod seers." The investigations of Greeff show that in the fovea centralis of the rat also rods alone are present and are extremely fine (thickness 0.75 μ), while the existence of a few cones is only known by the occurrence of cone granules in the outer granular layer.

"Rod seers" then view everything, even in broad daylight, as colorless, and, in case their fovea centralis has no rods, are, at this spot, totally blind, like ordinary persons in darkness. Totally color-blind persons see the sun-lighted landscape as a rod landscape, as we see it by faint moonlight. Total color-blindness is therefore a very marked defect. Some persons are, however, partially color-blind, by which is

[a] W. Zenker, Lehrbuch der Photochromie, Braunschweig, Fr. Vieweg u. Sohn, 1900.

generally meant that they confuse colors rather than are actually blind to any, and indeed they confuse pigments only, while pure spectral colors are distinguished by them almost as well as by persons of normal vision.

Similar as the two systems may be in many respects, there are yet several noteworthy differences, which appear best in the observation of a pure, brilliantly colored, and strongly lighted spectrum.

(1) While normal eyes distinguish red, yellow, green, blue, and violet, to the color-blind the blue-green zone appears without color, merely having a gray white luminosity ("neutral" zone of the color-blind).

(2) To color-blind persons the red end of the spectrum is shortened as compared with the blue.

(3) To color-blind persons a mixture of red and blue produces white, whereas such a mixture is rose-red to normal eyes.

The yellow and blue parts of the spectrum appear as vividly to color-blind persons as to those of normal vision, and so also do yellow and blue pigments. From this it follows that the color vision of the color-blind is effected by the cones like the color vision of normal eyes. In view of the fact that we do not know what are the color differentiating organs of the cones it is doubly difficult to assign causes for these various differences in color vision. Do these differences perhaps depend on a different structure of the cones?

Struck by the coincidence of the "neutral" zone with the color of maximum sensitiveness for rod vision, the thought forced itself to my attention that the peculiarities of color-blindness might be explained by supposing that the retina of a color-blind person in the region of direct vision where normal eyes have only cones contains rods as well.

Without ascertaining whether this idea is new or old, I present the following experiment to prove that the peculiarities of color-blindness are found in peripheral vision with normal eyes when care is taken to perceive them:

Probably few persons have ever carefully examined a bright spectrum under oblique vision. Upon thus observing a long stretch of the spectrum there is seen, in fact, as I had expected, a colorless brilliant white "neutral" zone lying in the place of the blue-green. Futhermore, the red end of the spectrum is shortened, and only reddish yellow and blue appear as vivid colors.

But a further consequence follows from the hypothesis that color-blind persons have both rods and cones all over the retina, including the fovea centralis. For if this is the reason why the color-blind see a mixture of red and blue as white, normal eyes ought to receive the same impression with oblique vision. Such is indeed the case

when the red and blue ends of the spectrum are superposed and obliquely observed.

This is otherwise shown by recombining a prismatic spectrum to produce white, but with the interposition of a screen which cuts off the yellow, green, and blue-green colors. Then the mixed field appears of a brilliant rose-red by direct vision, but a brilliant white when obliquely observed. For a check the red or blue may alternately be cut off, and then by oblique vision the apparently white field is correctly seen in the remaining active color. There is a striking appearance peculiar to the obliquely observed mixed field which gives one the impression that it is self-luminous or fluorescent.[a]

It is hard to say why it is that color-confusing persons see red and green pigment fields as gray-white and confuse them, while persons of normal vision sharply distinguish between them. A possible explanation might be that in bright light the fovea centralis is the principal agent of vision overcoming the peripheral retinal field, and that we see extensive bright fields not at one time but by sweeping over them with the fovea. Thus we cease to distinguish the colored papers confused by the "color-blind" only when we really observe them obliquely, so that their colors are lost in gray-white, even in daylight. In the condition of adaptation to obscurity, on the contrary, the fovea centralis is excelled by the peripheral region of the retina rich in rods, so that we no longer perceive the impressions of the fovea. (Compare Purkinje phenomenon.)

A greater difficulty seems to me to be that according to this hypothesis of color-blindness color-blind persons ought to perceive with direct vision also the Purkinje phenomenon and the displacement of the "neutral zone" which follows diminution of brightness. As Professor Nagel has been good enough to inform me, however, the Purkinje phenomenon absolutely ceases with him, at least at the fovea centralis.[b] Since, however, his fovea centralis is color-blind, I find myself compelled to add a second hypothesis, as follows:

The rods which occur in the fovea centralis and part of those in the macula lutea of color-blind persons must have lost their readiness of adaptation, and therefore are equipped with a higher sensitiveness for vision in strong lights than those of normal persons.

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[a] These color-mixing experiments were successfully performed by Professor Pringsheim, Doctor Gehrcke, and myself in a room which was lighted by two incandescent lamps, although, to be sure, feebly.

[b] If this is so with Professor Brodhun (who confuses red and green) also, then reasoning backward it follows that his fundamental experiment on the displacement of the neutral zone (a distinct proof of the competition of rods and cones) owing to the smallness of the field of the Helmholtz color-mixing apparatus, must have been performed unconsciously with extra foveal—that is, peripheral, retinal vision.

We will distinguish these rods as "central" and "bright-vision" rods to distinguish them from "peripheral" or "obscure-vision" rods. In order to prove their existence there is necessity for physiological experiments of a kind suited to distinguish the differences that occur between normal and color-blind persons in direct central vision of fields of different size. The Purkinje phenomenon and the displacement of the "neutral" zone with diminishing light intensity must be more accurately studied with different individuals in order to recognize how far the rods extend toward the fovea centralis in normal eyes, and where the "central" rods of the color-blind begin to be capable of adaptation and become "peripheral."

Perhaps this hypothesis might also be tested by anatomical researches on the retinas of color-blind persons, although it would be difficult to distinguish the "central" rods from the cones, for it appears that the cones approach more nearly to the rods in structure the nearer they lie to the center. Besides this the anatomist must be informed whether he is examining normal or color-blind eyes.

When I found that this (possibly not original) hypothesis had not as yet been carefully tested, I thought it worth publishing even if hereafter found to be false, since the careful experiments which its testing demands can not but throw light on this interesting subject. There appears to be no logical or zoological argument opposed to it, for since there are animals with more cones than rods (birds) and animals and men with rods only (animals living in darkness and the totally color-blind), and since persons of normal vision lie between these classes and possess more rods than cones and one spot entirely rod-free, why may there not be individuals having rods in this small spot, too? And if this is the case, then it is not strange that these central rods by continued usurpation of the place of the cones should have become bright-vision organs, and have lost their adaptive quality. The fact of the great number of color-blind persons (3 per cent of males and one-fourth of 1 per cent of females) supports the hypothesis, for it readily explains the great variations between individuals. For, according to the number of "central" rods, the degree of their sensibility, the extent of the area over which they have lost adaptability, and the degree to which they have supplanted the cones, by such gradations may normal color perception degenerate into the various degrees of color confusion, or even into total color-blindness.

FIG. 1.—PHOTOGRAPH OF LIGHTNING FLASH.

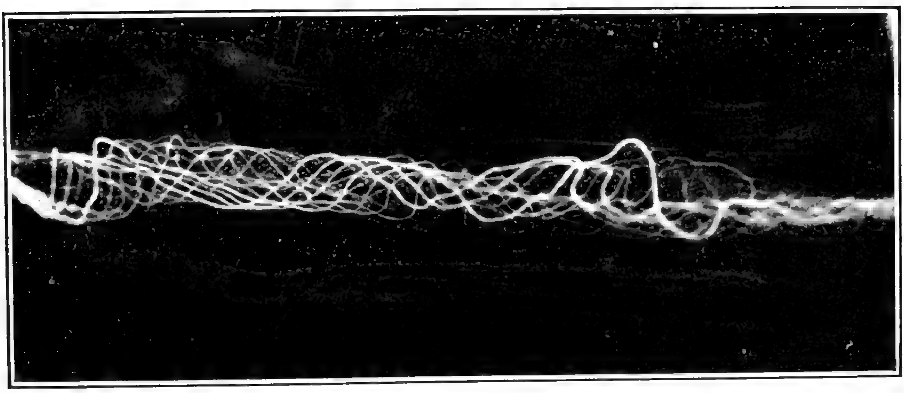
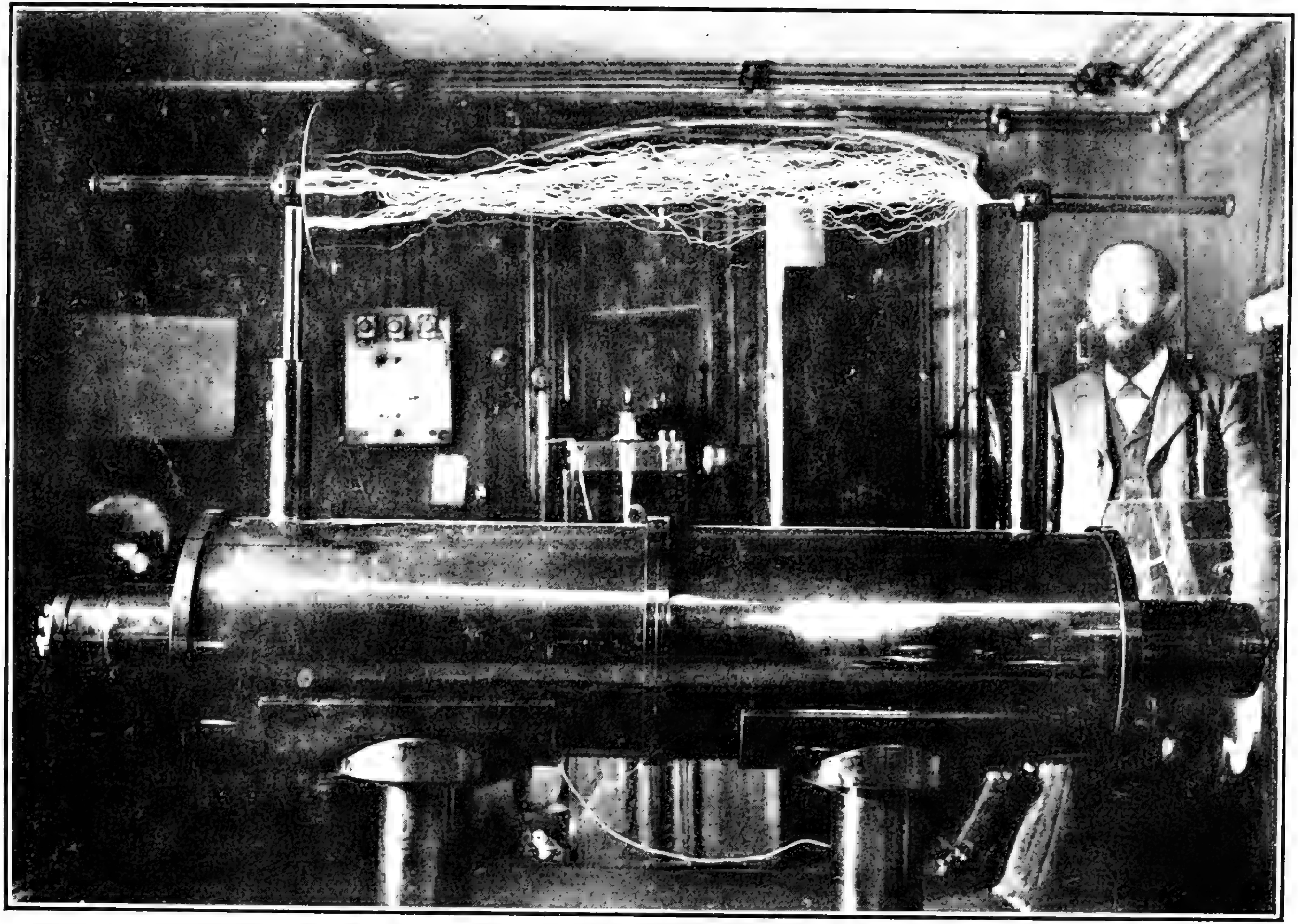


FIG. 2.—PHOTOGRAPH OF INDUCTION COIL SPARK.



KLINGELFUSS' PATENT INDUCTORIUM, PRODUCING SPARKS 120 CM. IN LENGTH, BUILT FOR THE POTSDAM ASTROPHYSICAL OBSERVATORY.

A LIGHTNING SPIRAL OBSERVED NEAR BASEL.[a]

By Fr. Klingelfuss.

On the night of July 15, 1902, between 11 and 12 o'clock, I obtained, in a fixed camera, a photograph of a very extraordinary lightning phenomenon. The flash occurred in an east-southeast direction, as viewed from the center of the city of Basel, and extended nearly horizontally from north toward south, or, as shown in figure 1, plate I, from left toward right. Not all the details seen in the photograph could be recognized by the eye, nor could I determine the distance from my standpoint to the scene of the discharge, because of the simultaneous sound of thunder from another flash. As the lens of the camera was uncovered for this exposure only a few seconds, it is probable that all that is shown in the illustration represents but one discharge.

Besides a pencil of parallel rays (caused probably by partial discharges torn apart by wind currents), such as is familiar from the photograph of H. Kayser,[b] the plate which is here shown contains two very distinct whirls of bright lines and a third fainter one. In addition there may be recognized a great number of bright lines running parallel to the axis of these spirals. Within the pitch of a single line of the spiral 50 or 60 parallel lines may be counted.

Inasmuch as a similar screw-shaped formation may be observed under certain conditions in the discharge of an induction coil, it seems highly probable that we have here to do with a spiral lightning discharge. Thus when a very great quantity of electricity is discharged with the bluest possible sparks and without strong aureole or arc there are produced magnificent spirals.[c] Figure 2, plate I, shows an instantaneous exposure of about 0.05 second duration on such a discharge from an induction coil giving sparks 50 cm. long. The greater the quantity of electricity in the discharge the more

[a] Translated by permission from Annalen der Physik, Leipzig, No. 1, 1903.
[b] H. Kayser, Wied. Ann. 25, p. 131, 1885.
[c] E. Ruhmer, Elektrotechn. Zeitschr. 21, p. 152, 1900.

regular are the spirals, as is to be expected. In order to fulfill the conditions above mentioned, a very high frequency is of course required, such as may be obtained with the electrolytic interrupter. Such spirals depend on the direction of the discharge in reference to the magnetic field of the induction coil or of the earth. Stereoscopic instantaneous exposures of less than 0.001 second show the image of an irregularly wound line turning sometimes left-handed and sometimes right-handed. With arc discharges no spirals are produced, probably because at the high temperatures accompanying the arc the magnetic lines of force are no longer present.

These conditions for the production of electric screw discharges seem to have been present in marked degree with the lightning discharge photographed. The discharge shows an extraordinary number of lines, partly in the spirals and partly running horizontally in the general path. Each line corresponds to a partial discharge, and the regularity of spacing of the lines in the spirals indicates a very large quantity of electricity discharged and a very high frequency. Undoubtedly the quantity discharged far exceeds anything of the kind we can obtain from an induction coil. This explains the great regularity of the lightning spirals as compared with those obtained from the induction coil. In the observed case, too, the earth's magnetic field was favorably situated, since the magnetic field produced by the spiral discharge coincided with it.

In order to determine if the lightning spiral produced any unusual magnetic field whose presence would be indicated by marked deflections of the magnetic needle,[a] I addressed communications to the Swiss meteorological Zentralanstalt at Zurich, and to the kgl. meteorologische Observatorium at Potsdam. The Swiss meteorological bureau was, unfortunately, unable to furnish the desired information, but I received from the director of the observatory at Potsdam the following negative reply:

> So far as concerns our observatory, it may be said in answer to your inquiry that on the day in question neither the terrestrial magnetic instruments nor the apparatus for observing atmospheric electricity (the latter records, within moderate limits, not only the potential difference but also the discharging capacity observed) showed any extraordinary behavior.

It is interesting to note that the photograph indicates that the partial discharges of this flash could not have been oscillating, but must have pulsed successively in the same direction in order to produce the direction of rotation here shown.

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[a] See Kr. Birkeland, Expedition Norwegienne de 1899–1900 pour l'etude des aurores boreales, p. 13, 1901. Jacob Dybwad, Cristiania.

VARIATIONS OF SPECIFIC GRAVITY.[a]

By G. W. A. KAHLBAUM.

In connection with researches on the distillation of metals, and while seeking to fix the specific gravity of the pure metals employed, I was led to make a thorough study of the subject of specific gravity measurements.[b] The grounds which led me to bestow so much attention on this subject apparently so threadbare are these: First, the exact measurement of specific gravity, particularly for solid bodies, is an extremely difficult piece of work, which can be successfully accomplished only by attending to certain not unimportant precautionary measures; and, second, the specific gravity to be determined is to be regarded rather as the expression of particular properties of the individual specimen examined than as a general property of all solids of the same kind.

This latter statement may be illustrated by the following determinations made on a small block of the purest Norwegian converter copper refinings, for which chemical analysis yielded 99.92 per cent copper, 0.02 per cent silver, 0.04 per cent nickel, and 0.02 per cent iron. Three small bars, 6 mm. in diameter and 45 mm. in length, were prepared, containing about 1.25 cm^3 each, and their specific gravity was determined within a mean error of 0.0016, as follows: I, 8.4412; II, 8.6926; III, 8.4297.

Thus it appears that three cylinders, turned from a single small block of copper, showed a variation of specific gravity through a range of 0.2629, or over $3\frac{1}{2}$ per cent of the whole specific gravity. Inasmuch as this was cast copper it was easy to explain the cause of the variation, for probably there were faults or blowholes in the casting. But the interesting and natural question arose, Where and when do such faults cease entirely?

With another cylinder of the same copper, weighing 79 grams, I made careful measurements by the volumetric method, depending

[a] Translated, by permission, from Annalan der Physik. Leipzig, No. 8, 1904.

[b] G. W. A. Kahlbaum, Zeitsch. f. anorg. Chem. 29, pp. 197–213, 1902.

on 140 separate determinations with the spherometer, and obtained the value of the specific gravity as 8.3774, which is a little less than that found for any of the smaller samples. It might be supposed that the difference of 0.32 between this value and that obtained for Sample II would be nearly the maximum obtainable. But Marchand and Scheerer [a] by very accurate determinations found for their highest value of the density of rolled and hammered copper plate 8.952, or 0.259 higher than my highest observed value, and, compared with my lowest value, showing a difference of 6.2 per cent.

It seems simple enough in the case of metals to do away with these differences of specific gravity by employing high pressures sufficient to close the faults produced in casting. But I have found in experiments with lead, cadmium, copper, tin, antimony, gold, and silver that up to a pressure of 10,000 atmospheres all these metals except cadmium show increased density with increased pressure, as was to be expected, but on increasing the pressure to 20,000 atmospheres these metals without exception diminished in density with the increased pressure. It is not implied that the density rises in all cases except that of cadmium up to 10,000 atmospheres pressure and then diminishes, but that if any decrease occurred below 10,000 atmospheres the density did not fall below the original value.[b] It would doubtless be of great theoretical interest to determine the exact pressure of maximum specific gravity, but working as hitherto with samples would consume much time, and it seemed to me that a shorter method based on electrical conductivity measurements would prove feasible. For if the electrical conductivity is measured continuously while the pressure is steadily augmented there must be a change in the march of the conductivity measurements when the pressure of maximum specific gravity is reached. Without going into a description of the experiments, it will suffice to say that I was led in this way to the examination of the specific gravity of wires. An alteration of the density implies a change in the molecular structure of the material. Such a change in the structure of wires is indicated by the fact that cold-drawn wires are brittle and liable to faults, and that in order to continue wire drawing a reheating is required.[c]

In wire drawing the metal must be drawn or, as in the case of sodium presses, squeezed through a hole with sharply defined edges. In this process there is formed at the back of the drawplate a ring of material, which is held back while the inner molecules by virtue of their cohesion are pressed or drawn through the opening. Metals

[a] O. L. Erdmann, Journ. f. prakt. Chem. 27, p. 206, 1842.

[b] G. W. A. Kahlbaum, Verhandl. d. Naturf. Gesellsch. in Basel, 15, p. 17, 1903.

[c] According to S. Kalischer (Ber. Deutsch. chem. Gesellsch. 14, p. 2750, 1881) zinc wire at temperatures above 300° becomes again brittle.

which are too soft—lead, for example—have too little cohesion, and are torn in attempting to draw them into wires.

In the process of wire drawing the metals are then in fact compressed, and in accordance with what has been said, a certain diminution of density is to be expected if the pressure is high enough, but there are no certain grounds to predict what might happen in further continuation of the process.

I had formerly found advantage in the use of the pyknometer, instead of the Archimedean method of determining specific gravity, but had found an improvement in the latter when the supporting wire is carefully platinized. By the friendly advice of Dr. Ch. Ed. Guillaume and Dr. P. Chappius, both of the Bureau International des Poids et Mesures in Pavillon de Breteuil in Sévres, who have been good enough to impart to me and my colleague the approved method employed at that institution, we have been able to avoid completely the error formerly encountered, and have employed the method of displacement, with the same success we had previously obtained by the pyknometer.

I give here only a small part of the results obtained, and choose for the purpose of illustration the experiments with platinum. It is not only a duty but a privilege to acknowledge in this connection the uncommon goodness of the firm of W. C. Heräus, in Hanau, who have not only furnished me liberally with the costly material, but also, to avoid error, have separately drawn all the wires required for the research.

Three parallel series of experiments were carried out, as follows: From a single bar of the Heräus commercial platinum pieces lying side by side were cut off, and three cylinders, each about 6 mm. in diameter and 35 mm. long, were turned to a uniform weight of 32 grams, then sent to us in Basel, where we determined their specific gravity. We then returned the samples to Hanau, where by rolling and hammering they were reduced to a diameter of 3 and length of 55 mm., suitable for wire drawing. The specific gravity of these samples was again measured in Basel. Returning them to Hanau, they were drawn successively to wires of 1, 0.7, and 0.4 mm. diameter. After each drawing complete determination of the specific gravities of these wires was made in Basel, and they were then before further drawing softened by heating to incandescence for three minutes. But before being further drawn—the wires were always cold drawn—the density of these softened wires was determined, so that we made 3 times 3 determinations on hard wire and the same number on soft wire.[a]

The results which I now proceed to give are the mean of three re-

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[a] Here follow in the original article full details of a single determination, from which the extreme care and accuracy of the work is apparent.

peated experiments with each of the three samples at each stage of its treatment. These measurements were made without exception by my colleague, Mr. F. Sturm, and the mean error of the 69 determinations has the extremely satisfactory value of only 0.0004.

TABLE I.—*Turned cylinders (I) and rolled and hammered cylinders (II).*

	No. 1.	No. 2.	No. 3.
I. Platinum cylinders	21.2136 21.2137 21.2137	21.3061 21.3062 21.3057	21.1326 21.1323 21.1330
	21.2137	21.3060	21.1326
II. Platinum cylinders, rolled and hammered	21.4317 21.4316 21.4308	21.4192 21.4190 21.4201	21.4147 21.4145 21.4140
	21.4314	21.4194	21.4144

These numbers confirm my earlier statement, and show that even with such a favorable material as platinum the results are strongly affected by the individuality of the sample examined. Samples cut from immediate proximity off the same bar show a difference of density of 0.1734.

By rolling and hammering the density is increased by, roughly, 1 per cent, and the difference of density between the three samples is at the same time reduced to about one-tenth its former magnitude. There is then nothing new in Table I, which merely proves the presence of pores or faults, which are diminished by the application of mechanical force.

Table II is, however, more interesting:

TABLE II.—*Rolled and hammered samples (II) and 1 mm. cold-drawn wire (III).*

	No. 1.	No. 2.	No. 3.
II. Platinum samples, rolled and hammered	21.4317 21.4316 21.4308	21.4192 21.4190 21.4201	21.4147 21.4145 21.4140
	21.4314	21.4194	21.4144
III. Platinum wire 1 mm. in diameter, cold drawn	21.4139 21.4136 21.4132	21.4232 21.4224 21.4223	21.4229 21.4234 21.4235
	21.4136	21.4226	21.4233

Sample 1, which had the highest density as hammered platinum, showed a diminution in specific gravity of 0.0178, which is a difference far beyond the mean error of measurement (0.0004) already given. Samples 2 and 3, which had been somewhat lower in density than No. 1, advanced somewhat, but, as we shall see, it is probable that behind this apparent increase a decrease is really hidden, and that samples 2 and 3 also would have showed a falling off had they

been first hammered to a somewhat more compact form. The maximum difference between samples has diminished to 0.0097.

Of greatest interest is Table III, which exhibits the variations of density between cold drawn and annealed platinum wires.

TABLE III.—*Platinum wire of 1, 0.7, and 0.4 mm. diameter cold drawn (III and V, VII) and afterwards heated to incandescence (IV, VI, and VIII).*

	No. 1.	No. 2.	No. 3.
III. Platinum wire 1 mm. diameter, cold drawn	21.4139 21.4136 21.4132	21.4232 21.4224 21.4223	21.4229 21.4234 21.4235
	21.4136	21.4226	21.4233
IV. Like III, except heated white hot for 3 minutes	21.4317 21.4312 21.4314	21.4324 21.4320 21.4325	21.4325 21.4320 21.4326
	21.4314	21.4323	21.4324
V. Platinum wire 0.7 mm. diameter, cold drawn	21.4180 21.4178 21.4186	21.4155 21.4159 21.4158	Lost.
	21.4181	21.4157	....
VI. Like V, except heated white hot 3 minutes	21.4310 21.4315 21.4316	21.4318 21.4313 21.4313	21.4354 21.4349 21.4355
	21.4314	21.4315	21.4352
VII. Platinum wire 0.4 mm. diameter, cold drawn	21.4144 21.4143 21.4138	21.4149 21.4146 21.4147	21.4337 21.4135 21.4130
	21.4142	**21.4147**	21.4134
VIII. Like VII, except heated white hot 3 minutes	21.4305 21.4310 21.4310	21.4304 21.4312 21.4313	21.4318 21.4322 21.4313
	21.4308	21.4310	21.4317

Such are the results, which confirm the earlier discovery that excessive compression diminishes the specific gravity. I have already drawn attention to the analogy here presented to the behavior of gases under high pressures, which are less compressible than Boyle's law requires.

The explanation of this curious behavior of wires may, however, depend on such factors as crystalline configuration, and, at all events, requires further experiments to determine.

A second new and very important result appears, that strongly compressed wires increase in specific gravity when heated to incandescence. This indicates that an increase of the kinetic energy of the molecules suffices to restore them to their normal relations, but I do not venture here upon any explanation of the phenomenon and content myself with pointing out this new and independent proof of the variability of specific gravity.[a]

[a] Here follows in the original article an explanation of the author's relations with Hr. W. Spring in connection with the publication of their joint researches bearing on this subject.

These experiments have lately been continued in Basel by my colleague, and he finds that glowed platinum wire 0.4 mm. in diameter of specific gravity 21.4317 fell off in density to 21.4133 when drawn to 0.1 mm., and on being heated white hot again rose to 21.4346. Wires of chemically pure platinum, an alloy of platinum with 10 per cent iridium, aluminum, and copper all behave in a similar manner, and rolled aluminum foil and hammered zinc plates as well.

A change of electrical conductivity had previously been noted after incandescence in cold-drawn wires of platinum, platinum-iridium, aluminum, and copper.

These researches will be continued in all the directions here indicated, and an attempt will be made to measure the alterations by the volumetric method.

SOME NEW MODES OF LIGHTING.[a]

By A. Berthier.

Incandescent petroleum oil lamps.—During the last quarter of a century the use of petroleum and its derivatives for illumination has been much restricted by the growth of incandescent lighting by electricity, acetylene, and illuminating gas; but quite recently there has developed a new use of petroleum oil for incandescent mantle lighting. Various systems have been proposed, of which the earlier ones depended on the carbureting of air by the aid of some special device and the distribution of this mixture under feeble pressure.

Owing to complications of the mechanism and the tendency of stoppage in conducting passages these earlier arrangements found little favor, but the inventors of the Washington, Kitson, and Glitsch systems have succeeded in avoiding separate mechanical contrivances and automatically produce the mixture of gas and air within the lamp itself.

In these new systems of lighting, a liquid is stored in a central reservoir, from which runs a conducting pipe to a special distributer, and thence small tubes lead the liquid to the several lamps or heaters to be supplied. In the Washington and Kitson systems petroleum oil is the liquid employed, while the Glitsch system uses benzine. The reservoir for the liquid may be either inside or outside the building, but for single lamps or heaters is often directly attached to the capillary tubes which supply the burners. These capillary tubes are of steel and hardly an eighth of an inch in external diameter, so that they may readily be hidden from sight, and are, indeed, both less visible and less dangerous than electric wiring. The tubes are tested to bear a pressure of 10 atmospheres, but in use are not required to withstand more than 4 atmospheres pressure. It is apparent, too, that with a liquid of such slight volatility as petroleum oil there is much less danger of explosion in consequence of leakage than with illuminating gas or, indeed, with benzine.

[a] Translated and abridged, by permission, from Cosmos, Paris, May 7, 21, June 18, 1904.

The Washington lamp is already well known, although of recent invention. It belongs to the type of lamps in which the combustible liquid is vaporized in a special chamber above and within reach of the flame. Air is admitted to this chamber and, mixing with the vaporized oil, is led by way of two large tubes at the side of the lamp to feed the flame. The vaporizing device is a simple metallic tube heated by radiation from the incandescent mantle which surrounds it. A cock at the lower end of this tube regulates the admission of the liquid, which, after being vaporized, passes out through a small orifice at the top and mixes with air in the chamber above. Thence the mixture is led downward through the two tubes at the side of the lamp and is conveyed to the burner through a wire netting. The incandescent mantle, which surrounds the vaporizer, is held by a metal support fastened to the vaporizer itself. Thus the flame which renders the mantle incandescent at the same time feeds itself by vaporizing the oil in the tube. In the earlier models the lamp required to be started by first burning a little alcohol in a cup below the burner so as to vaporize enough oil to begin the incandescence, after which, of course, the lamp continued to produce the vapor consumed. As first exhibited, the lamps were furnished in two types of two and three burners yielding, respectively, 500 and 750 candlepower, but recently M. Georges Washington, of Brussels, has devised other types of less intensity, and the company is now constructing portable lamps of about 50 candlepower.

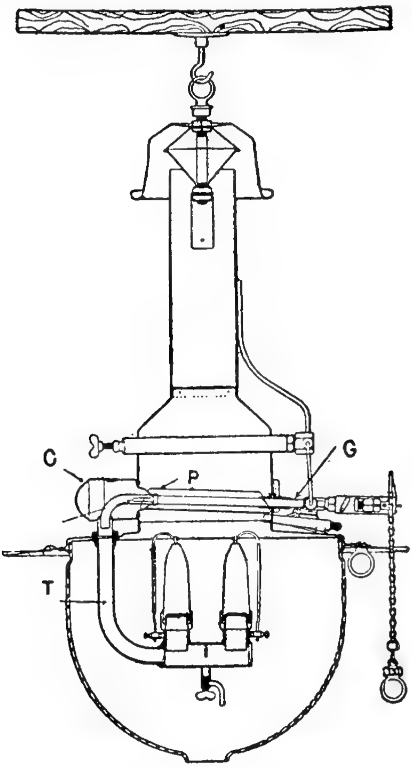

FIG. 1.—The Kitson lamp.

The Kitson system of lighting, introduced in Germany by a Dresden syndicate, is analogous to the preceding. An oil reservoir, conveniently placed outside the dwelling, communicates by capillary tubes to the burners. By means of a force pump an air pressure of about 4 atmospheres is produced over the oil in the reservoir, which is thus caused to circulate through the capillaries.

There are several notable differences between the Washington and Kitson lamps. In the latter a vaporizing tube, common to the several burners of a single lamp, runs horizontally over the burners, and upon

it is concentrated by metal screens the heat rising from the incandescent mantles. The vaporized oil escapes downward through a large tube at the side of the lamp and here, mixing with air admitted through a heated chamber, is led from beneath to the burners.

The light of the two-burner Kitson lamp is dazzling and reaches at least 1,000 candlepower. With specially favorable conditions, such as with a new mantle and a high pressure of oil, 1,500 or even 2,500 candlepower is sometimes obtained. Oil is consumed at the rate of about 0.2 liter (one-half pint) per 1,000 candlepower per hour. The light produced has a mellow, agreeable color, much warmer in tone than that of the electric arc or the incandescent gaslight. As already remarked, the intensity depends on the pressure, which is an inconvenience for a lamp of small oil capacity, but where there is a reservoir of large dimensions the diminution of pressure during twenty-four hours causes no considerable variation in the intensity of the lamp.

Of all methods of providing intense light, these which have been described are most economical. It is possible to combine in a single system lamps of great and relatively small intensity, and the material employed is common and inexpensive and may serve to produce both lighting and heating, or, indeed, motive power. There are no special dangers to be feared when the combustible liquid is placed outside the dwelling, and both the Washington and Kitson systems include an automatic valve to close off the circulation in case of leakage. The greatest objections are the use of liquid which has a disagreeable odor, tends to creep, and which sometimes yields a foul and disagreeable smoke. Finally, the production of the gas from the liquid under pressure produces a noticeable roaring sound. But for most purposes these inconveniences are of minor importance as compared with the great advantages of a superb quality of light at minimum cost.

No other mode of lighting can compare in cheapness with the petroleum incandescent lamp in countries where kerosene may be bought at a cost of from 2 to 4 cents a liter (8 to 16 cents a gallon). It is just to add that in cases where natural gas or water power furnishes an almost gratuitous source of energy the electric light may indeed compare in cheapness, but even then there must first be provided complicated and costly machinery.

Benzine is employed instead of petroleum in the Glitsch system, and although somewhat more dangerous, this liquid is cleaner and in certain other respects more suitable for the purpose. It is unnecessary to use pressure greater than 1 atmosphere to circulate benzine through the capillary tubes, and the lamps may be fed by merely placing the reservoir somewhat above them and depending on the force of gravity. The method of starting combustion is very simple and consists merely in heating the burner for twenty or thirty seconds in an auxiliary flame of alcohol in order to begin the vaporization of the benzine.

As compared with petroleum incandescent lighting, the benzine system is more expensive and less suitable for brilliant illumination, such as is required in streets, railway stations, and factories, but on account of its greater convenience and cleanliness is perhaps better suited to lighting of dwellings, heating, and cooking purposes.

Alcohol may also be employed for incandescent lighting, either alone or in a mixture, and may be distributed under feeble pressure; but at present the use of alcohol for this purpose does not appear to be practically successful. In 1902 it was stated that alcohol lamps of from 60 to 800 candlepower burned from 10 to 16 grams per candlepower hour, while lamps of from 100 to 1,000 candlepower employing mixtures of alcohol and hydrocarbons in equal ratio consumed 5 to 10 grams of alcohol per candlepower hour. To make alcohol lighting commercially successful it is necessary to find a solid or liquid hydrocarbon soluble in alcohol and very cheap, which will give rise to enhanced heating effect with diminished cost.

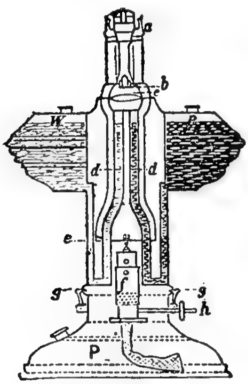

FIG. 2.—The Altmann lamp (cross section).

A new incandescent petroleum lamp has appeared which consumes a mixture in equal parts of the vapors of water and petroleum. Readers may recall descriptions of an ingenious little water vapor blow torch. The new Altmann burner is evidently based on the same idea, but is more compact, for it combines the reservoirs of water and oil and requires no wick, like Mercier's blow torch. In the Altmann burner complete combustion of the hydrocarbon is effected in presence of the water vapor, and the flame, in absence of the incandescent mantle, is blue like that of the Bunsen gas burner. A vertical section of the lamp is shown in fig. 2. In the reservoir, which is divided in two sections, is the water W and the petroleum P. The two liquids pass by separate channels *e* to the vaporizing tubes *d d*. By means of a small auxiliary lamp placed centrally at *f*, the gas tubes are heated to the temperature required to vaporize the liquids, thus producing a mixture of gases in the chamber *c*, heated both by the radiation of the incandescent mantle and by the little burner *f*. This auxiliary burner is fed with combustible liquid contained at P near the foot of the lamp. On leaving the chamber *c*, the mixed vapor traverse a tube *b* to a burner analogous to those employed for incandescent lighting with ordinary illuminating gas. In the models now in use the intensity of illumination ranges from 80 to 100 candlepower. The consumption of petroleum is about a liter (one-fourth of a gallon) in twenty-four hours, so that the cost is about 0.002 cent per candlepower hour. A heater is constructed by the same company which also appears to be very economical.

New methods of electric lighting.—As early as 1878 Archereau, Carré, and Gauduin sought to augment the luminosity of the electric arc by rendering the arc itself as well as the positive carbon incandescent. For this purpose they mixed with the carbon of the electrodes suitable substances such as oxides of calcium or magnesium; but unfortunately there occurred a precipitation of the refractory oxides upon the lower carbon, and a formation of scoria which resulted in a prejudicial unsteadiness for illumination. After the Welsbach mantle attained success, new efforts were made to apply this principle of incandescence of the arc, and Monsieur Bremer exhibited at the exposition of 1900 a model having four special carbons, and in which the light produced in the arc was reflected downward. The presence of mineral matter resulted in increasing the luminous surface, modifying the color of the light as desired, and in diminishing by one-half the current consumption for a given illumination.

A considerable number of concerns, notably in Germany, are now producing flaming arc lamps more or less patterned after that of Bremer. The principal differences consist in the varied construction of the electrodes, but all are composed of mixtures of carbon and some salt of calcium, usually fluorspar. Professor Wedding, having studied the influence of this substance on the consumption of energy in the lamp, has found that the most favorable conditions are found with 15 per cent fluorspar. Electrodes of this composition are found to consume but 0.15 watts per candle, as compared with 0.5 watts for the ordinary arc.

Doctor Arndt's researches at the Technische Hochschule in Berlin have shown that the operation of the flaming arc does not involve any appreciable production of objectionable gases. Furthermore, the light produced is of a yellowish-red color and much less cold and harsh than that of the ordinary arc. It more resembles sunlight in color, and penetrates better through fog than the light of shorter wave length produced by the ordinary arc.

The Bremer arc requires the use of special lamps, but by employing trizonal carbons A. Blondel has avoided this inconvenience. Minerals are contained in the two interior zones, and such arcs, consuming only 3 amperes, have been found to give nearly three, and similar arcs, consuming 9 amperes, more than four, times the efficiency of the ordinary arc light consuming equal energy.

In the same general category belongs the lamp with three electrodes and two arcs, devised by L. Sigfried Andersson, of Stockholm. For the purpose of increasing the area of luminous surface, and at the same time producing incandescence within the arc, there is introduced between the two carbons which carry the current a third cylinder, formed of a more refractory substance than the two others. The regulation of this lamp is very delicate, and is effected in a most

ingenious manner by means of a Wheatstone bridge, made up of the two side arcs themselves and two suitable resistances, which are wound as electromagnets in such a manner as to operate the regulating mechanism. The central cylinder thus carries the current only when the bridge is thrown temporarily out of balance.

Instead of rendering the arc luminous by the aid of refractory oxides, the same result may be obtained by introducing a combustible liquid or powder through a hollow electrode. This device has been tried by J. Akermann, but it does not seem likely to prove very practicable.

All these devices of introducing foreign substances into the arc are evidently for the double purpose of diminishing its resistance and of augmenting its luminosity, and there seems to be no reason why a conducting vapor like that of mercury should not be substituted for the solid particles of carbon or of metallic salts or oxides which have been used for this purpose. The Cooper-Hewitt lamp is the development of this idea. Everybody is familiar with the Geissler tubes, in which light is produced by an electric current traversing a rarefied gas. It is possible, as Tesla has shown, to excite such tubes to luminosity by simply placing them in a varying electrostatic field of high frequency. About 1892 Arons showed that mercury vapor traversed

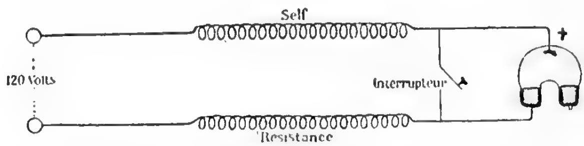

FIG. 3.—Disposition of current in Cooper-Hewitt lamp.

by a current emits light, but there was no idea at that time of employing this device for illuminating purposes. The credit for this discovery rests, therefore, with Cooper-Hewitt, who has devised a mercury lamp of great simplicity, composed of a glass tube with electrodes at the two ends. The negative electrode is mercury itself, and the positive electrode may be either mercury, iron, or other metal. Platinum wires sealed into the glass conduct the current to the electrodes. When cold, the pressure of the mercury vapor is very small, but when heated by the passage of the current the mercury vapor pressure rises to about 2 mm. of liquid mercury, or about one four-hundredth of an atmosphere.

Cooper-Hewitt lamps operate under a difference of potential of 110 volts, of which about 80 are absorbed in the arc. Since the internal resistance is very high at first, this potential difference is insufficient to start the light, and several thousand volts are required for a brief interval at the start. Accordingly some auxiliary device has to be provided, as is the case with the Nernst lamp, to heat the conductor to the temperature at which the ordinary voltage will maintain incandescence. For example, the required voltage may be ob-

tained by introducing a self-induction coil in the lamp circuit, and shunting across the lamp a quick-acting oil interrupter. The extra current at break suffices to start the arc, which thus primarily excited is able to continue, and the self-induction thereafter plays the part merely of reducing variations of the current. Figure 3 shows the disposition of circuit adopted by Cooper-Hewitt.

Usually the tubes have the form of an inverted U, with short arms. Each arm contains mercury, and at the top is an iron electrode. Thus the arc may pass between iron and mercury or between two mercury electrodes as desired. In the former case the distance between electrodes is about 7 cm. and in the latter about 9 cm. These lamps are exhausted to about the same degree as ordinary incandescent electric lights, and they may be run at any current strength between 0.5 and 5 amperes. Below 0.5 amperes the arc ceases, and above 5 amperes the tube breaks, owing to the heat produced. The difference of potential between terminals varies from 82 to 87 volts for U tubes. The efficiency of these lamps is said to be upward of three times as high as that of the ordinary arc.

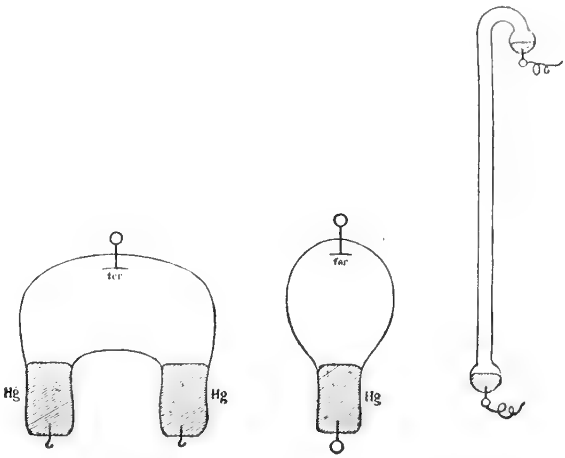

FIG. 4.—Different forms of the Mercury vapor lamp.

Other methods of starting the mercury arc have been proposed by various physicists, and one of the most simple, devised by Doctor Weintraub, involving the use of a small auxiliary arc, avoids recourse to a high voltage at starting. It therefore appears that there are ready means of overcoming this primary obstacle to the use of the mercury arc; but a second and very serious objection lies in the green color of the light produced. Being wholly without red rays, this light gives a ghastly appearance to the objects illuminated. On the other hand, according to German experiments the light has a great power of penetration, and it is besides highly actinic, and thus suitable for photographic purposes, and, moreover, the color is not fatiguing to the eyes. It has been proposed to introduce a warmer tint by interposing a red mantle, but this device greatly diminishes the efficiency. Perhaps better results may be reached by introducing traces of certain neutral gases, or substituting some amalgam instead of pure mercury.

In all the methods of lighting thus far mentioned in this article the source is a very intense light restricted to a comparatively narrow area; but there has very recently been installed in New York a system of electric lighting by vacuum tubes of great length, whose comparatively feeble brightness is counterbalanced by their great area of luminous surface. Plate I shows an application of this method of lighting within an apartment. While not yet fully perfected, this system gives excellent promise, both as regards cheapness and general satisfactory qualities of illumination. A principal difficulty seems to consist in obtaining a suitable gaseous conductor whose spectrum shall approximate that of diffused daylight instead of being restricted to a few wave lengths like that of mercury, but partial success in this respect is already achieved.

A DRAWING-ROOM WALL AND CEILING EFFECT OBTAINED WITH MOORE TUBES.

From Cassier's Magazine.

PROGRESS IN WIRELESS TELEGRAPHY.[a]

By William Maver, Jr.[b]

The possibility of telegraphing without wires by means of electric waves in free space was demonstrated when Dr. H. Hertz, in 1887 and 1888, holding a so-called "electric eye," consisting of a ring of copper wire about 16 inches in diameter and broken at one point, a few feet from the spark gap of an induction coil, or oscillator, was able to detect minute sparks jumping across the break in the copper ring.

In 1889 Doctor Branly discovered that metal filings, which, when made part of an electric circuit, had normally a very high electrical resistance, but became good conductors of electricity when electric oscillations were set up in the circuit, and that they retained their conducting qualities until shaken up.

The art of wireless telegraphy took a long forward step when, in 1894, Dr. (now Sir) Oliver Lodge made his notable experiments before the Royal Institution, in which he used, as a transmitter of electric waves, the Hertz or Righi oscillator, and as a detector of those waves, the Branly coherer, consisting of a tube filled with metal filings in an electric circuit containing an electric bell. To insure the filings resuming their state of nonconductivity upon the cessation of the electric oscillations, Doctor Lodge caused a "tapper," operated by clockwork, to strike the tube continuously. A bell or relay in the coherer circuit could thus be kept in vibration during the continuance of electric oscillations and would become passive when the oscillations ceased, and in this way signals could be transmitted. Lodge believed that the limit of sensitiveness of this apparatus would be half a mile, but even this distance would have advanced the signaling distance four-hundredfold beyond the point at which Doctor Hertz had left it.

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[a] Reprinted by permission, after revision by author, from Cassier's Magazine, June, 1903. In connection with this article it may be found interesting and profitable to refer to his earlier one, "Wireless telegraphy—its past and present status and its prospects," Cassier's Magazine, January, 1902, and General Appendix to Smithsonian Report, 1902, page 261.

[b] Author of "American telegraphy" and "Maver's wireless telegraphy."

The art, however, received its most powerful impetus when Marconi, in 1898, using vertical wires 80 to 100 feet high at each station, a 10-inch spark induction coil, and an improved Branly-Lodge coherer, succeeded in transmitting wireless signals a distance of about 40 miles, which distance within another twelve months, by using still higher vertical wires and more improved apparatus, he increased to 280 miles over water.

The writer on other occasions has remarked that had the progress of wireless telegraphy rested with Hertz's discovery of the copper ring detector, its utility for commercial purposes would have been very limited—in fact, nil, since the utmost distance at which signals can be detected by that device is about 8 or 10 feet. It might now be said that while improvements in the construction of the filings coherer, together with increased height of the vertical wires and an increase in their number and in the power of the transmitting apparatus, render it possible to receive signals with this form of detector at a distance of 400 to 500 miles under favorable conditions, still, had there been no other receiving instrument than the filings coherer, important as the improvement in that instrument has been, there would perhaps have been little or no progress to note relative to the speed of transmission by wireless telegraphy, which, with the filings coherer as a receiver, may be placed at from eight to twelve words per minute. The action of the filings coherer is inherently sluggish in the production of perfect signals, the cohering and "tapping back," added to the intertia of the moving parts of the tapper, the relays, etc., all tending to that result.

It may be noted in this relation that in ordinary shipboard practice to-day the distance signaled with the filings coherer does not much exceed 50 miles.

It was therefore very obvious to all concerned in the art of wireless telegraphy that a thing much to be desired was the invention or discovery of a coherer or detector which would, so to speak, "close" automatically on the occurrence of electric oscillations and "open" automatically when the oscillations ceased, or vice versa. As frequently happens in such cases, this desideratum, an autocoherer, was not very long in forthcoming.

One of the first devices that bore promise of fulfilling the foregoing requirement is known as Schaefer's "anticoherer." This consists of a silver film deposited on glass. Across this film slits are traced, these being covered by a thin layer of celluloid. When the silver film is made part of an electric circuit it is found that the resistance of the circuit rises when electric oscillations are set up therein, and when the oscillations cease the resistance automatically falls. This action, it will be observed, is the reverse of what occurs in the Branly filings coherer; hence the term anticoherer. It has been surmised that the

effect of the film of celluloid, which does not penetrate into the interior of the slits, is to prevent the dissipation of the particles of silver in the slits, and whose motion under the influence of electric oscillations probably accounts for the variations in the resistance of the circuit. Carbon filings were also found to decohere automatically; but these devices were not extensively used in practice, if at all.

The next most important autocoherer was that due to Castelli, known for a time as the Solari coherer, also as the Italian navy coherer. This autocoherer was used by Marconi in his first experiments in trans-Atlantic wireless telegraphy. It consists of a tube similar to the filings coherer, but instead of metal filings between the ends of the iron or carbon rods within the tube, a drop of mercury is employed. In the circuit with the coherer there is a small battery and a telephone receiver. On the arrival of electric oscillations the mercury appears to cohere to the carbon or iron, with the result that the resistance decreases, but immediately rises when the oscillation ceases, these variations in the resistance of the circuit setting up noises in the telephone, which can be read as dots and dashes when messages are transmitted. This autodetector has the disadvantage that after some use it becomes rather unreliable in operation, to prevent which frequent renewals of the mercury and cleansing of the tube are necessary.

Subsequently Marconi devised an autocoherer, known as a magnetic detector, which has been used in his trans-Atlantic and other long-distance experiments. This coherer consists of a primary and secondary coil of wire (wound over a coil of fine iron wires), the inner coil of which is connected to the vertical wire in a manner practically similar to that in which the filings coherer is connected. The outer coil contains in its circuit a telephone receiver, but no battery. This detector of electric waves is based on the observed fact that when a magnet, such as the iron core, is caused to undergo slow changes of magnetism, electric oscillations in the outer coil bring about rapid changes in the magnetism of the core, which, in turn, set up currents in the inner coil, and these are heard as clicks in the telephone receiver.

The slow changes of magnetization referred to are brought about as follows: An endless rope or core of fine iron wires is represented in figure 1 by *c c; p p* are pulleys about an inch in diameter, operated by clockwork. The iron rope passes over the pulleys and through a small glass tube upon which the coils referred to, *w w*, are coiled. The iron core is magnetized by two horseshoe magnets (not shown in figure), the ends of

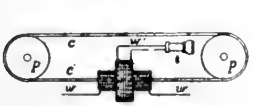


Fig. 1.—Marconi magnetic detector.

which are laid with their similar poles together on the coils, their position on the coils being changed until the best results are obtained.

In the United States, De Forest and Fessenden have also devised autocoherers, which are used in their respective wireless systems. The De Forest autocoherer, which has been termed a "responder," comprises a tube with tin electrodes or plugs running into the bore. Between the inner ends of the electrodes is placed a viscous substance, such as glycerin, in which some lead oxide is suspended as a depolarizer. In shunt circuit with the tube are a small battery and a telephone. Normally the battery sets up an electrolytic action, which tears off small particles of tin from the positive electrode. These particles "bridge" or "thread" over the space between the ends of the plugs, with the result that the resistance is much decreased. Incoming electric waves, however, establish electric oscillations in the responder circuit, which disrupt the threads or bridges, whereupon the resistance is at once greatly increased. These variations in the resistance of the circuit are readily indicated in the telephone, and thus when the train of electric waves is broken into dots and dashes of the Morse code messages are easily received. This autocoherer, it will be observed, is of the anticoherer type.

The Fessenden detector, or "barretter," employs a different principle from either of the foregoing. Fessenden takes advantage of the facts that an electric current increases the temperature of a conductor through which it passes, and that an increase of temperature of the conductor increases the electrical resistance of the conductor, and contrariwise. He therefore employs a very thin loop of platinum wire contained in a small glass bulb, the whole so disposed that heat will be quickly conducted from the platinum wire. In the circuit of this loop he includes a small battery and a telephone receiver, suitably connected with the vertical wire. When oscillatory currents are set up in the circuit, rapid variations of the temperature of the platinum loop and corresponding variations in the resistance of the circuit are produced, these in turn affecting the telephone receiver practically as in the instances already given.

More recently both Fessenden and De Forest have used a detector, termed by the former a "liquid barretter" and by the latter an "electrolytic receiver," which consists of an exceedingly fine short platinum wire in a dilute nitric acid solution. The device is outlined in figure 2, in which V is a vessel containing the liquid L; B is the fine wire, the extent of the immersion of which is adjusted by a suitable screw. The lower wire, m', enters the liquid from the bottom of V. Its size is not material. Connection with the receiving oscillating circuit is made by means of the wire w and the wire w'. In the usual shunt circuit from the oscillating circuit there are included the detector, a small battery, and a telephone receiver.

According to Fessenden, this device operates by reason of the fact that practically all the resistance of the circuit is localized and concentrated within a short distance of the point where the cylindrical platinum wire projects into the liquid. The current from the small battery flows through the shunt circuit, but owing to the high resistance of the circuit this current is normally weak. The incoming electric oscillations decrease this resistance, varying the circuit, and thereby producing audible signals in the telephone.

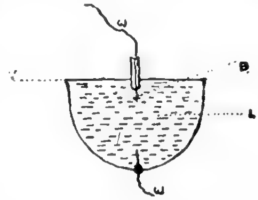


Fig. 2.—Liquid detector.

According to De Forest, the operation of this detector is due to the setting up of a counter electromotive force of polarization in the cell, which makes the cell apparently nonconducting. Incoming oscillations cause a temporary annulment of the insulating film of oxygen gas surrounding the positive electrode, varying the current in the local circuit, with the desired result of producing signals readable on the telephone. There are now two other claimants for the inventorship of this detector, namely, H. K. Vreeland of this country, and Schloemilch of Germany, which fact may be considered a fair indication of the practicability and reliability of the device.

Still another autodetector is that successfully employed in the Lodge-Muirhead wireless telegraph system. It is shown in figure 3 and is known as the oil-film detector. It consists, essentially, of a rotating steel disk D′, operated by clockwork. The periphery of this disk enters a vessel *r* containing mercury *m*. The disk is normally prevented from making direct contact with the mercury by a film of mineral oil, but electric oscillations in the circuit cause the mercury and disk to cohere with the usual result. The detector circuit is completed by wires *w w′*.

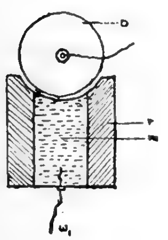


Fig. 3.—Lodge-Muirhead autodetector.

By reason of the sensitiveness of the telephone receiver, changes of current that would not affect a relay are observable in the former instrument. Hence, by the use of this instrument much weaker electric waves are detected than would be the case with the filings coherer. Furthermore, the autodetector responds instaneously, so that a higher rate of signaling is obtainable by its means, a speed of 40 words a minute having already been obtained by De Forest. Marconi predicts that ultimately he will be able to transmit one hundred words per minute by means of his detector and suitable automatic transmitting and receiving apparatus.

Important improvements have also been made in the matter of syntonic, or tuned, wireless telegraphy, by means of which it is hoped to eventually transmit two or more different messages at the

same time to and from the same stations. By tuning is meant giving the respective transmitting circuits a fundamental period of oscillation, which can be done by proper adjustment of the capacity and inductance of the oscillating circuits, analogously as the rate of vibration of a tuning fork may be varied by varying its elasticity, its inertia, etc. Thus far it does not appear that this desirable result has been satisfactorily accomplished. By means of tuned circuits, however, the principle of sympathetic resonance is brought into use, and thus, with a given amount of electrical energy at the transmitter and a detector of given sensitiveness, it is feasible to transmit messages to a greater distance than would be the case with untuned circuits. It may be added, also, that Fessenden, De Forest, and others have succeeded very well in cutting out interference from other stations by means of tuning devices.

For long-distance transmission, Marconi, De Forest, and others have successfully resorted to the use of dynamo machines for the production of electric oscillations of much greater energy than are obtainable by the most powerful induction coils. The height and number of vertical wires used in long-distance transmission have also been increased, towers 250 feet high, with 50 or more vertical wires, being employed by several of the wireless telegraph companies.

Considerable progress has also been made in telegraphing overland without wires, by means of portable outfits, for military purposes, much of the work of this kind having been done by Siemens & Halske, of Berlin, Germany, using the Braun system. The apparatus is transported on carts, and the vertical wire is elevated by means of a captive balloon, or, in fair weather, by kites. The distance to which signals can be transmitted by this apparatus is said to be 60 miles, and it is anticipated that within a short time all the important armies of the world will be supplied with apparatus of this general type. Recent experiments by Marconi and Slaby-Arco in Europe, and by De Forest in the United States, have shown that it is possible to transmit wireless signals to distances of from 300 to 1,000 miles overland.

The most important commercial use to which this art has yet been put, however, is that of making possible communication between vessels at sea and between vessels and the mainland, which would still appear to be its greatest sphere of usefulness, and every week sees a larger number of vessels and shore stations equipped with wireless telegraph outfits.

ELECTRIC WELDING DEVELOPMENT.[a]

By Elihu Thomson.

The art of welding iron is probably as old as the earliest production of that metal by man. In fact, the reduction of iron in the primitive forges demanded the union by welding of the reduced particles, for no true fusion could have resulted, the percentage of carbon present being too low. Until the closing years of the last century iron was the only weldable metal, if we except gold and platinum—too expensive for common application.

The fact that nearly pure iron, so difficult to melt, becomes quite plastic at high temperatures, while the oxide, or black scale, melts long before the metal itself becomes fluid, thus providing a liquid flux which is squeezed out during the process of union, accounts for the unique position which iron held until recent years. When, however, the heating effects of electric current energy, so perfectly under control, were applied to weld metals, a metal or alloy which would not weld became the exception instead of the rule, as before. Much of the former work of the smithy fire is now accomplished by the electric welding transformer, and although many metals are easily manipulated by the electric process, iron, of course, still occupies, as ever, the principal place.

The electric weld is becoming a more and more important factor in many industries. During recent years the extension of its application has been steady, and each year has witnessed its entrance into new fields. Sometimes, indeed, new manufactures, or new ways of obtaining results, have been based upon its use. The electric welds under consideration are the results of that operation of uniting two pieces of metal by what is known as the "Thomson process," first brought out by the writer and rendered available in commercial practice a considerable number of years ago. The rapidity, flexibility, cleanliness, neatness, accuracy, and economy of the electric process has won for it such an important standing in the arts that many future extensions in its application are assured.

The uniformity of the work, the control of the operation, the extreme localization of the heat to the particular parts to be united, and the fact that the process is not limited to iron and steel, but can

[a] Reprinted, by permission, from Cassier's Magazine, New York, June, 1904.

deal equally well with other metals, such as copper, brass, bronzes, and even lead, are characteristics of the electric welding operation.

In its simplest form an electric welder consists of a special transformer, the primary circuit of which receives current from an electric station or dynamo generator at a voltage usually from 100 to 500 times that required to make a weld. The copper secondary circuit of the transformer is generally only a single turn of very large section, so that it may develop an extremely heavy current at from 2 to 4 volts—an electric pressure so low that it can not give the least effect of shock, and one for which there is no difficulty in securing perfect insulation. The work pieces are held in clamps or vises, attached to or carried upon the terminals of the single-turn secondary circuit. The control of the clamping devices and the current switch is either manual or, in some cases, entirely automatic. Without attempting to enumerate the many applications of electric welding in the arts, we may refer to a few examples.

In the wagon and carriage industry the process is applied in the production of tires of all sections, axles, hub, spoke, and sand bands, fifth wheels, shifting rails, steps, shaft iron, etc., while it has found a large use in the welding into continuous strips or bands of the wires inclosed in rubber tires for holding them in place. The larger part of the dash-frames used in carriages in the United States are now probably made by electric welding, while iron and steel agricultural wheels are built up or have their parts united by electric welds.

To enumerate the many applications to the bicycle industry would be almost to catalogue most of the metal parts of this useful machine. It must be borne in mind, too, that a welding machine, slightly modified, is equally applicable for locally heating parts in electric brazing or hard soldering, for upsetting, and for bending or shaping. Bicycle crank hangers, pedals, seatposts, fork and fork ends, frames, and brake parts thus become products in which the welding transformer has its part. It has found a useful field also in tool manufacture, such as drills, reamers, taps, band and circular saws, drawing knives, carpenter's squares, printer's chases, etc., and electric welding has a closely related use in the production of machine parts. Cam shafts and crank shafts are made from drop forgings welded together, teeth are inserted into gear wheels, and teeth are welded to saw bodies, including stone saws. Such things as inking rolls in printing machines and fallers for looms are additional examples.

In the wire industry the part played by electric welding is already quite important, and becomes steadily more so. Besides the mere simple joining of wires of iron, steel, or copper into long lengths, the welding of wire or strip into hoops for barrels, tubs, pails, etc.,,is supplanting the older forms. Numerous machines are in operation turning out electrically welded wire fence, much as a loom turns out cloth.

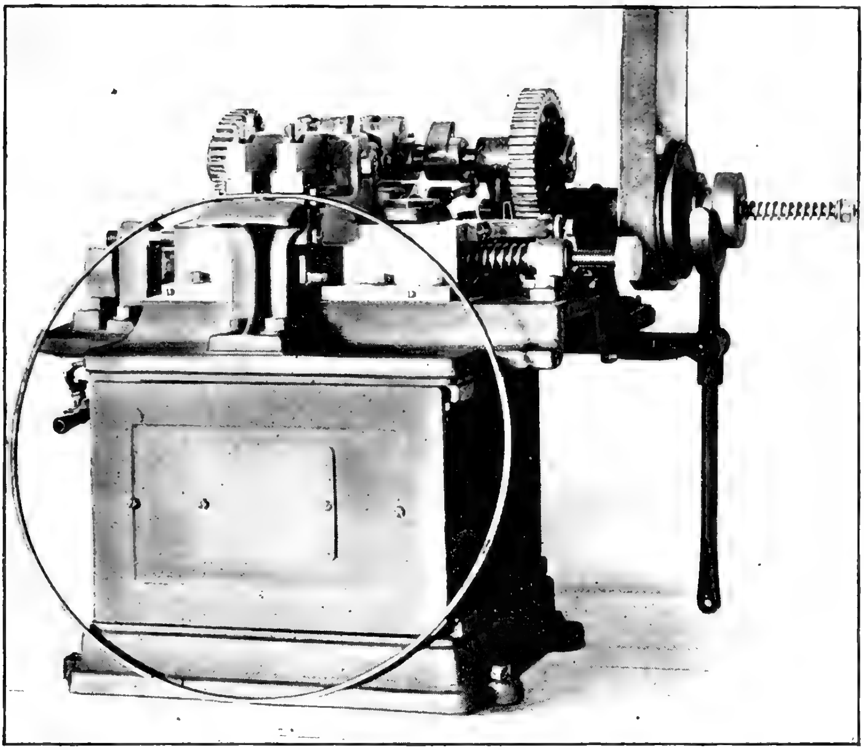


FIG. 1.—AN ELECTRIC TIRE-WELDING MACHINE, MADE BY THE THOMSON ELECTRIC WELDING COMPANY, LYNN, MASS.

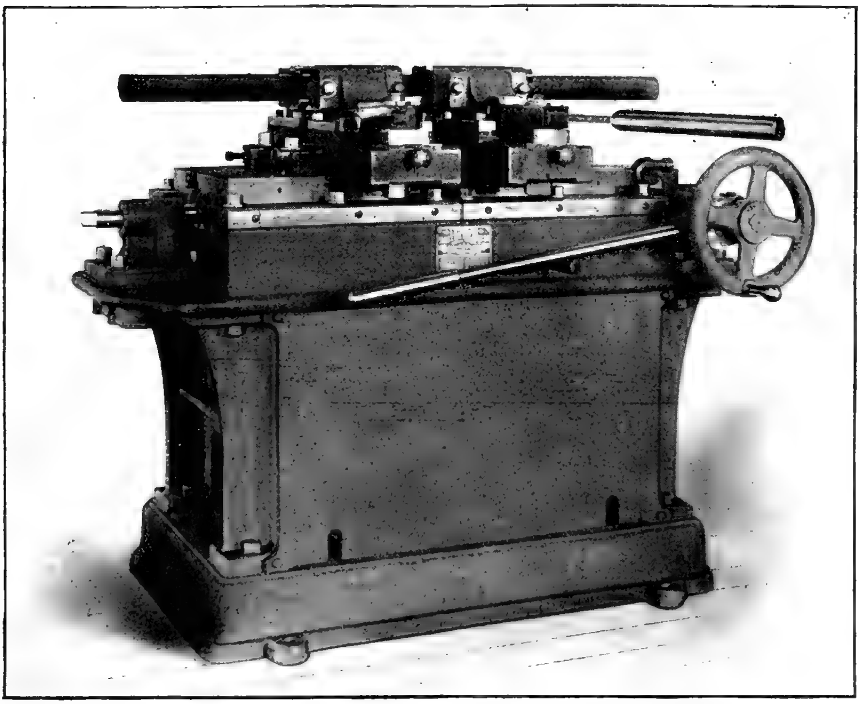
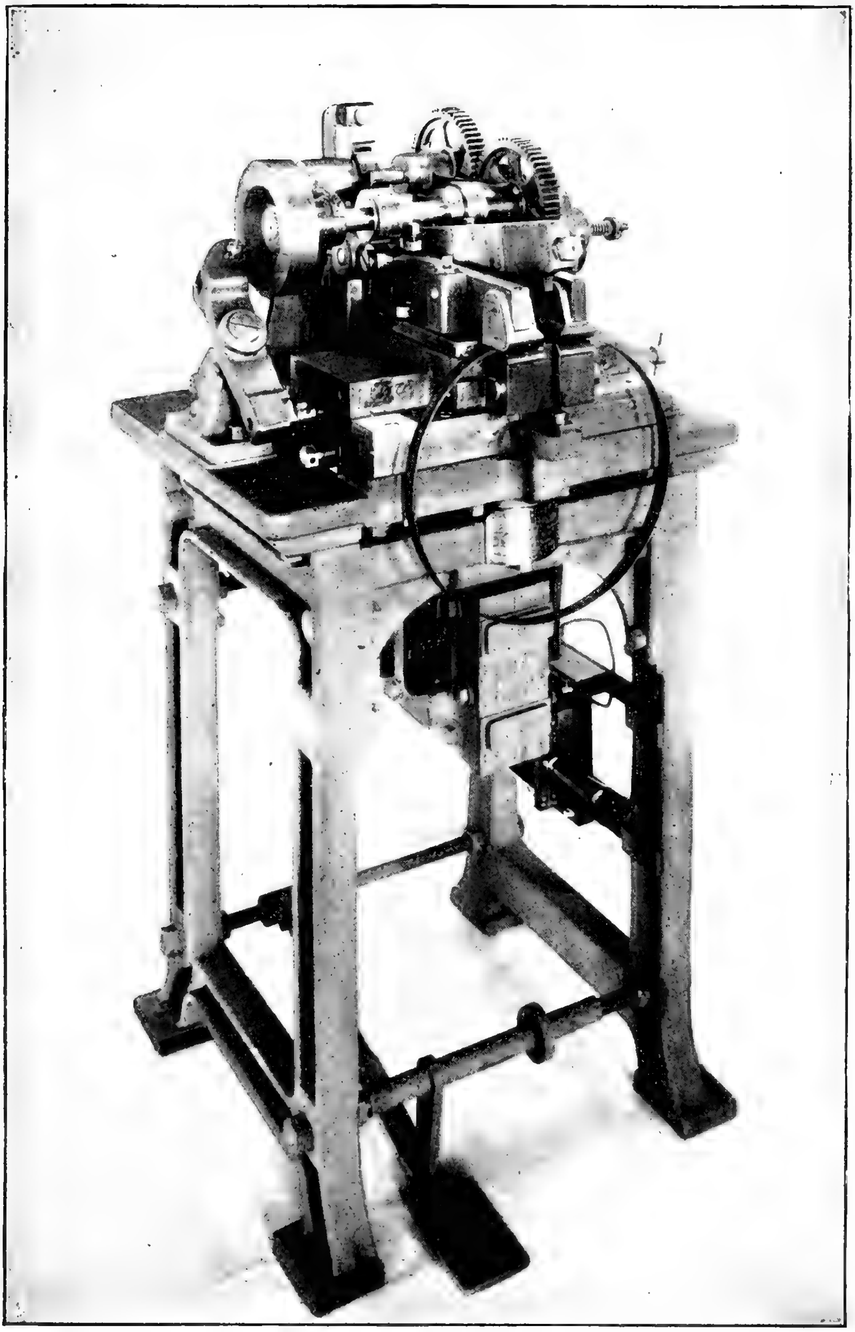


FIG. 2.—AN ELECTRIC WELDING MACHINE FOR IRON AND STEEL PIPE.



ANOTHER FORM OF HOOP OR TIRE WELDING MACHINE.

In pipe bending and coiling, as in uniting ordinary lengths of pipe into very long lengths without screw joints, the electric weld has a special adaptability. Hundreds of miles of street-railway rails have been welded into continuous lengths and now exist in many cities. Where rails are bonded only the electric welder assists in the production of brazed or welded bonds. It is a wide range between buckles, typewriter bars, and umbrella rods to the local annealing of armor plates on warships, but the electric welder covers that range. It is no wider, however, than that from fine wires of a diameter of one-fiftieth of an inch up to heavy steel wire for the armor of submarine cables, and again up to street-railway rail joints.

In recent years elaborate machinery for the actual production on a large scale of steel tubing from flat stock or skelp by the progressive welding of a longitudinal seam has been put into operation. The long strip, or skelp, is rolled up so that its edges meet. In this condition it enters between the welding rolls, which pass the heating current locally across the edges to weld them, and the operation is progressive from one end of the pipe to the other as it is fed into the machine. The result is a pipe of which the walls are of even thickness and the diameter uniform. This pipe can be afterwards drawn, if needed, to the exact size desired. Very thin pipe can be made of steel, the longitudinal seam or weld in which is a delicate bead along the length—a beautiful product, for the extreme localization of the heat has allowed preservation of surface and finish of the metal outside the joint. Taper tubes, such as are used for bicycle front forks and the like, are easily made.

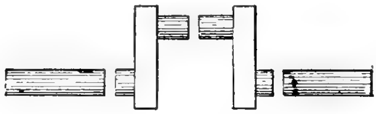
A similar machine for large work has lately been constructed, and by its use large diameter tubes or shells, up to 16 inches in diameter, are produced from sheet steel or iron. The illustration shows such a machine ready for operation. The welding transformer is at the top of the machine, and the secondary circuit has for its terminals two copper rolls inclined to each other on two nearly horizontal shafts adjustable in position over the work. Below are the guide rolls, one on each side on vertical shafts, and between these the shell to be welded passes with its meeting edges uppermost and in contact with the copper contact rolls. As the metal shell passes along under these rolls the joint is progressively heated by the welding current crossing it, and the weld is finished by the side pressure of the guiding rolls. The process, as well as the resulting welded product, is unique.

For a considerable time past welding machines have been applied to the production of bands or tires from stock of varying width, thickness, and sectional form. More recently the practice of welding plain bands or cylindrical rings, and afterwards rolling them with the form of section desired, has been largely adopted; such as, for example, in

the production of automobile wheel rims, bands for roving cans, stove rings, etc.

Very different from this is the formation of crank shafts, now demanded in great numbers for engines of automobiles. These are made from drop forgings and round shaft stock by uniting the pieces, as in the annexed sketch, and afterwards lightly machining and finishing the approximately correct shaft, as produced by welding. No legend.

Besides the banding of wire or strip of such comparatively frail containing vessels as barrels or pails, the electric weld finds application in the forming and capping of metal vessels for withstanding high pressures, such as soda-water cylinders, carbonic-acid reservoirs, and steel bottles for nitrous oxide gas.



One of the most interesting of the more recent applications is that of welding hollow steel handles on cutlery, such as table knives and forks. The operation is remarkable for the celerity and neatness of the work, the articles being finished by silver-plating and polishing, as usual. The hollow handle is drawn from thin steel, and united to the knife blade or to the fork, as the case may be, in a special welding machine, there being no brazing or other operation of joint-forming required. There is, indeed, no limit to the delicacy of the work which may be undertaken, provided only the welding apparatus is equally refined.

In the simpler types of electric welders, especially where the machine is designed to do a variety of work, perhaps of different forms or sizes of pieces, or both, the adjustments are usually manual; that is to say, the operations of clamping the pieces and applying the electric current and mechanical pressure are each controlled by the operator. In other cases, such as in the welding of copper or aluminium wire, the machine is, at least in part, automatic. The pressure is automatically applied and the welding current is cut off automatically upon the completion of the joint; the placing of the pieces in the clamps and the switching on of the current is, in this case, manually performed.

In other, more completely automatic, types, particularly adapted for rapid repetition of the same operation on identical pieces, the machine runs continuously, and its sequence of actions is definitely determined by the construction. In such cases a source of power, as by a belt, drives the machine, the movement so imparted having the effect of clamping the pieces as they are fed to the machine, putting on the current, applying the pressure, cutting off the current, and releasing the pieces.

The mechanism which has been developed for these purposes dis-

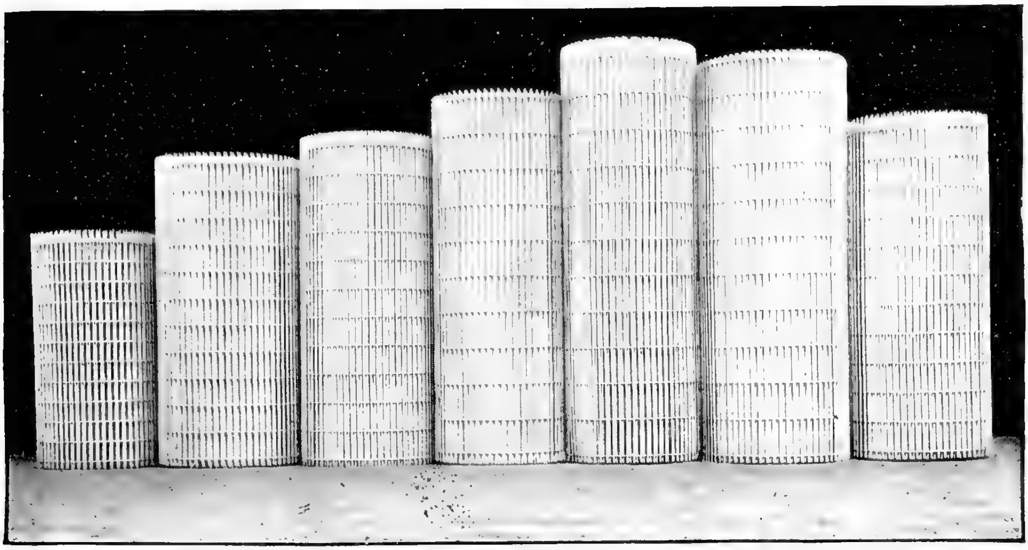


FIG. 1.—ROLLS OF ELECTRICALLY WELDED WIRE FENCE OF VARYING WIDTH AND MESH.

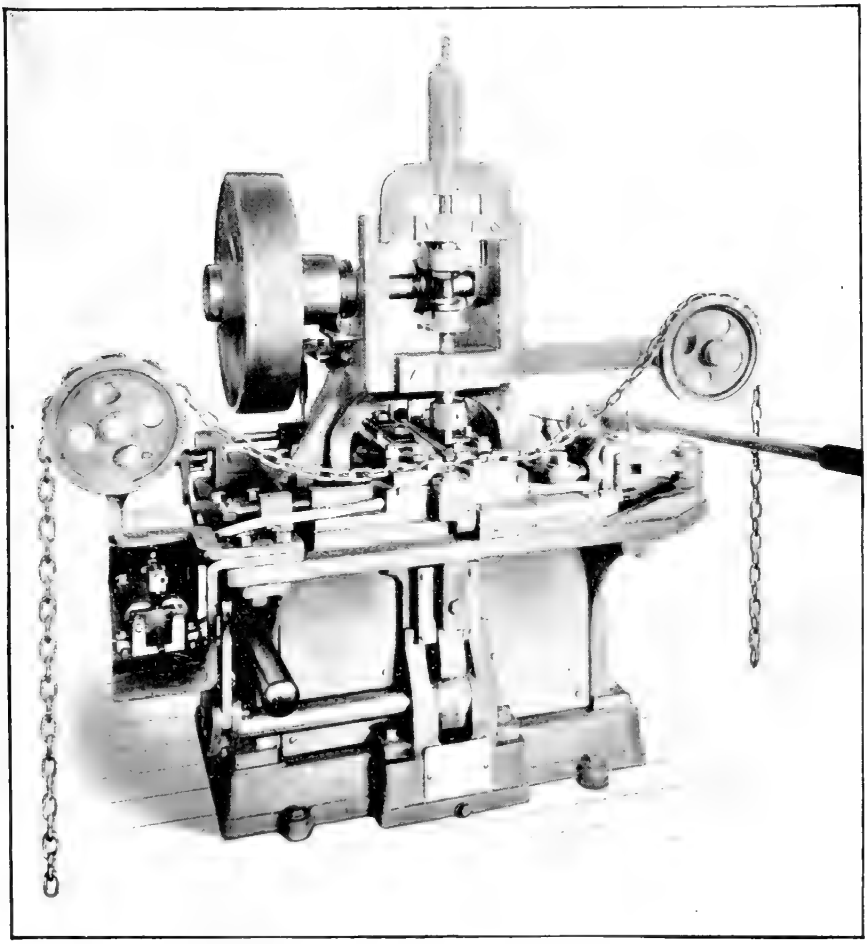
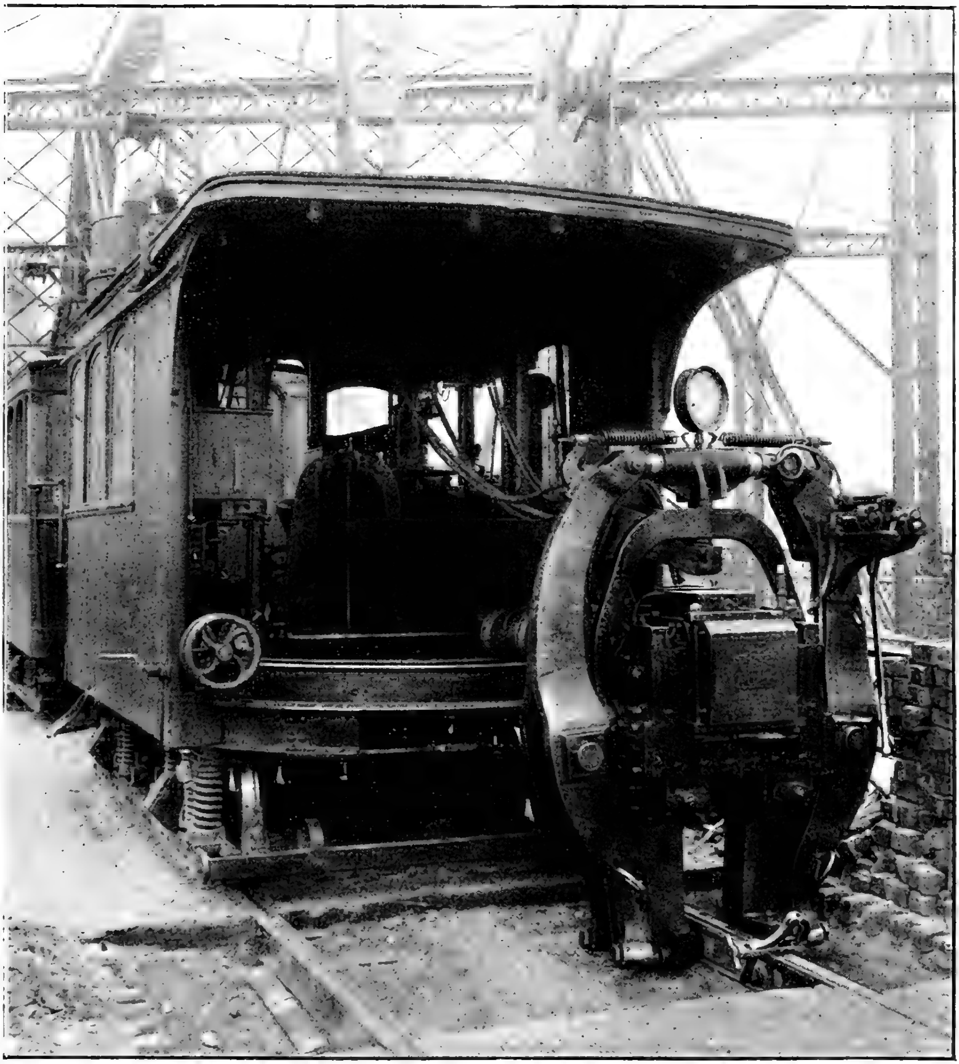
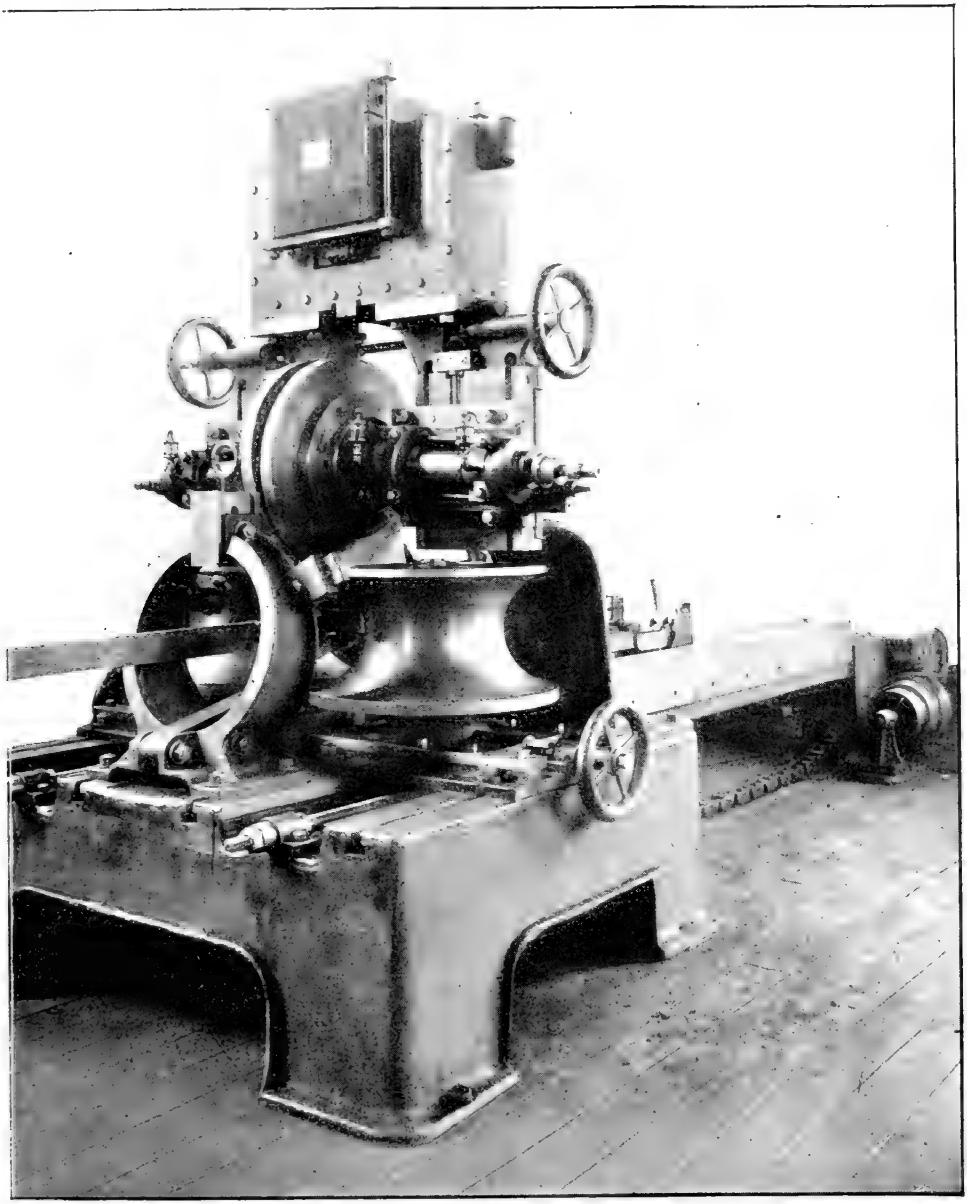


FIG. 2.—AN ELECTRIC CHAIN-WELDING MACHINE.



ELECTRIC RAIL WELDING ON STREET RAILWAYS, AS PRACTICED BY THE LORAIN STEEL COMPANY, JOHNSTOWN, PA., AND LONDON.



A WELDING MACHINE FOR LARGE TUBES OR SHELLS UP TO 16 INCHES IN DIAMETER, USED BY THE STANDARD WELDING COMPANY, OF CLEVELAND, OHIO.

plays, in many instances, much ingenuity. In these machines the duty of the attendant is limited to the mere placing of the pieces between the clamping jaws, just before they are clamped, and the work is characterized by rapidity and by uniformity of the results.

More completely automatic still are machines for the production of wire fencing and for the consecutive welding of the links of chains. In these the operation, once started, goes on uninterruptedly so long as the work holds out or until the stock undergoing operation is exhausted. In the fence machines, of which 15 are now in existence, galvanized iron wires are fed from reels parallel to one another, at distances apart depending on the mesh desired. These may correspond to the warp in weaving. Transversely to these and at intervals corresponding to the mesh selected are fed wires, cut from a reel, which transverse wires are the verticals in the finished fence itself and correspond to the weft in weaving. A series of small welders are automatically brought into operation to weld each transverse wire to the longitudinals where the two cross. This done, the web so formed moves forward, the operation repeats itself, and so on continuously. The welding is in this case practically instantaneous, and all of the movements of the machine are entirely automatic.

In this way it is possible for a single machine to turn out many thousands of feet of fencing per day with a width of mesh from 2 or 3 inches up. Less wire is used than where the joints are made by twists or loops, and the stability or fixedness of position of such joints as are made is much more assured. Figure 1, plate III, will give some idea of the neatness of this product of the electric welding loom.

While in most cases of electric welding the joint forms what is known as a butt weld, with a burr or extension of metal at the joint, which, according to conditions, is either allowed to remain or is forged down or dressed off, there is no difficulty in making lap welds electrically, and some of the recent work of the electric welder is of that character. While, too, the usual welding concerns pieces of the same metal, as iron to iron, steel to steel, or copper to copper, combination welds of different metals are made with facility in many cases, as when brass and iron are united.

In the working of high-carbon steels the usual precautions to prevent burning or injury to the metal are, of course, required; but, on account of the delicacy of heat control, they are more easily adopted.

Quite recently automatic chain welders have been put into use, and electrically-welded chain work will probably soon attain an importance not second to the other principal applications which have been briefly described.

THE HISTORY OF SOME DISCOVERIES OF PHOTOGRAPHY.[a]

By Robert Hunt.

A. Heliography—The Process of Monsieur Niepce.

Monsieur Niepce was the first inquirer who appears to have produced permanent pictures by the influence of the sun's rays. This process—heliography—is in many respects peculiar, which renders it necessary, although his preparation was only acted on by an exposure of many hours to full sunshine, to give a particular account of it; the more so, as some points of considerable interest require further elucidation.

The substance employed by Monsieur Niepce was asphaltum, or bitumen of Judea. He thus directs its preparation: "I about half fill a wineglass with this pulverized bitumen; I pour upon it, drop by drop, the essential oil of lavender[b] until the bitumen is completely saturated. I afterwards add as much more of the essential oil as causes the whole to stand about three lines above the mixture, which is then covered and submitted to a gentle heat until the essential oil is fully impregnated with the coloring matter of the bitumen. If this varnish is not of the required consistency it must be allowed to evaporate slowly, without heat, in a shallow dish, care being taking to protect it from moisture, by which it is injured, and at last decomposed. In winter or during rainy weather the precaution is doubly necessary. A tablet of plated silver or well cleaned and warm glass is to be highly polished, on which a thin coating of the varnish is to be applied cold, with a light roll of very soft skin. This will impart to it a fine vermilion color and cover it with a very thin and equal coating. The plate is then placed upon heated iron, which is wrapped around with several folds of paper, from which by this method all moisture had been previously expelled. When the varnish has ceased to simmer the plate is withdrawn from the heat and left to cool and

[a] Revised by T. W. Smillie, U. S. National Museum, from Chapters II–IV of A Manual of Photography, by Robert Hunt. Fourth edition. London and Glasgow, 1854. Octavo, pp. 329.

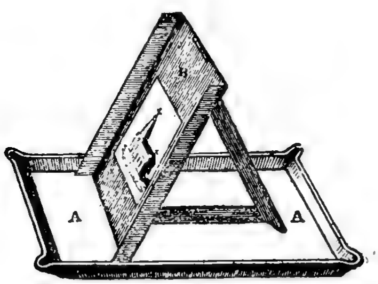
[b] The English oil of lavender is too expensive for this purpose. An article sold as the French oil of lavender, redrawn, is very much cheaper and answers in every respect as well, if not better.

dry in a gentle temperature and protected from a damp atmosphere. In this part of the operation a light disk of metal with a handle in the center should be held before the mouth in order to condense the moisture of the breath."

The plate thus prepared is now in a fit state for use and may be immediately fixed in the correct focus of the camera. After it has been exposed a sufficient length of time for receiving the impression a very faint outline alone is visible. The next operation is to bring out the hidden picture, which is accomplished by a solvent.

This solvent must be carefully adapted to the purposes for which it is designed. It is difficult to fix with certainty the proportions of its components, but in all cases it is better that it be too weak than too strong. In the former case the image does not come out strongly; in the latter it is completely destroyed. The solution is prepared of one part—not by weight, but volume—of the essential oil of lavender, poured upon ten parts, by measure also, of oil of white petroleum. The mixture, which is first milky, becomes clear in two or three days. This compound will act until it becomes saturated with the asphaltum, which is readily distinguished by an opaque appearance and dark brown color. A tin vessel somewhat larger than the photographic tablet and 1 inch deep must be provided. This is to have as much of the solvent in it as will cover the plate. The tablet is plunged into the solution, and the operator, observing it by reflected light, begins to see the images of the objects to which it has been exposed slowly unfolding their forms, though still veiled by the gradually darkening supernatant fluid. The plate is then lifted out and held in a vertical position till as much as possible of the solvent has been allowed to drop away. When the dropping has ceased, we proceed to the last, and not the least important, operation of washing the plate.

This is performed by carefully placing the tablet upon a board B (fig. 1), fixed at a large angle in the trough A A, the supports being joined to it by hinges to admit of the necessary changes of inclination under different circumstances. Two small blocks, not thicker than the tablet, are fixed on the board on which the plate rests. Water must now be slowly poured upon the upper part of the board and allowed to flow evenly over the surface of the picture. The descending stream clears away all the solvent that may yet adhere to the varnish. The plate is now to be dried with great care by a gentle evaporation. To preserve the picture it is requisite to cover it up from the action of light and protect it from humidity.



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The varnish may be applied indifferently to metals, stone, or glass, but Monsieur Niepce prefers copper plated with silver. To take copies of engravings, a small quantity of wax is dissolved in essential oil of lavender and added to the varnish already described. The engraving, first varnished over the back, is placed on the surface of the prepared tablet, face toward it, and then exposed to the action of the light. In the camera obscura an exposure of from six to eight hours, varying with the intensity of the light, is required; while from four to six hours is necessary to produce a copy of an engraving. The picture, in the first instance, is represented by the contrast between the polished silver and the varnish coating. The discoverer afterwards adopted a plan of darkening the silver by iodine, which appears to have led the way to Daguerre's beautiful process. To darken the tablet, it was placed in a box in which some iodine was strewed and watched until the best effect was produced. The varnish was afterwards removed by spirit of wine.

Of the use of glass plates Monsieur Niepce thus speaks:

Two experiments in landscape upon glass, by means of the camera, gave me results which, although imperfect, appear deserving of notice, because this variety of application may be brought more easily to perfection, and in the end become a more interesting department of heliography.

In one of these trials the light acted in such a way that the varnish was removed in proportion to the intensity with which the light had acted, and the picture exhibited a more marked gradation of tone, so that, viewed by transmitted light, the landscape produced, to a certain extent, the well-known effects of the diorama.

In the second trial, on the contrary, the action of the luminous fluid having been more intense, the parts acted upon by the strongest lights, not having been attacked by the solvent, remained transparent. The difference of tone resulted from the relative thickness of the coatings of varnish.

If this landscape is viewed by reflection in a mirror on the varnished side and at a certain angle, the effect is remarkably striking, while, seen by a transmitted light, it is confused and shapeless, but what is equally surprising, in this position the mimic tracery seems to affect the local color of the objects.

A statement that M. Niepce was enabled to engrave by light went the round of the press; but this does not appear to have been the case. All that the author of heliography effected was the etching of the plate, after it had undergone its various processes, and the drawing was completed by the action of nitric acid in the usual manner. The parts of the copperplate protected by the varnish remained, of course, unacted on, while the other parts were rapidly attacked by the acid. Niepce remarks that his process can not be used during the winter season, as the cold and moisture render the varnish brittle and detach it from the glass or metal.

M. Niepce afterwards used a more unctuous varnish, composed of bitumen of Judea dissolved in animal oil of Dippel. This composi-

tion is of much greater tenacity and higher color than the former, and, after being applied, it can immediately be submitted to the action of the light, which appears to render it solid more quickly, from the greater volatility of the animal oil. M. Daguerre remarks that this very properly diminishes still further the resources of the process as respects the lights of the drawings thus obtained. These processes of M. Niepce were much improved by M. Daguerre, who makes the following remarks on the subject:

The substance which should be used in preference to bitumen is the residuum obtained by evaporating the essential oil of lavender, which is to be dissolved in alcohol and applied in an extremely thin wash. Although all bituminous and resinous substances are, without any exception, endowed with the same property—that of being affected by light—the preference ought to be given to those which are the most unctuous, because they give greater firmness to the drawings. Several essential oils lose this character when they are exposed to too strong a heat.

It is not, however, from the ease with which it is decomposed that we are to prefer the essential oil of lavender. There are, for instance, the resins, which, being dissolved in alcohol and spread upon glass or metal, leave, by the evaporation of the spirit, a very white and infinitely sensitive coating. But this greater sensibility to light, caused by a quicker oxidation, renders also the images obtained much more liable to injury from the agent by which they were created. They grow faint and disappear altogether when exposed but for a few months to the sun. The residuum of the essential oil of lavender is more effectually fixed, but even this is not altogether uninfluenced by the eroding effects of a direct exposure to the sun's light.

The essence is evaporated in a shallow dish by heat till the resinous residuum acquires such a consistency that when cold it rings on being struck with the point of a knife, and flies off in pieces when separated from the dish. A small quantity of this material is afterwards to be dissolved in alcohol or ether; the solution formed should be transparent and of a lemon-yellow color. The clearer the solution the more delicate will be the coating on the plate. It must not, however, be too thin, because it would not thicken or spread out into a white coat, indispensable requisites for obtaining good effects in photographic designs. The use of the alcohol or ether is to facilitate the application of the resin under a very attenuated form, the spirit being entirely evaporated before the light effects its delineations on the tablet. In order to obtain greater vigor the metal ought to have an exquisite polish. There is more charm about sketches taken on glass plates, and, above all, much greater delicacy.

Before commencing operations the experimenter must carefully clean his glass or metal plate. For this purpose emery reduced to an impalpable powder mixed with alcohol may be used, applying it by means of cotton wool, but this part of the process must always be concluded by dry polishing, that no trace of moisture may remain on the tablet. The plate of metal or glass being thus prepared, in order to supply the wash or coating it is held in one hand and with the other the solution is to be poured over it from a flask or bottle having a wide mouth, so that it may flow rapidly and cover the whole surface. It is at first necessary to hold the plate a little inclined, but as soon as the solution is poured on and has ceased to flow freely it is raised perpendicularly. The finger is then passed behind and below the plate in order to draw off a portion of the liquid, which, tending always to ascend, would double the thickness of the covering. The finger must be wiped each time, and be passed very rapidly

JOSEPH NICÉPHORE NIEPCE.

Original heliotype in U. S. National Museum.

FROM A PERMANENT PHOTOGRAPH MADE BY JOSEPH NICÉPHORE NIEPCE IN 1524.

Original print in U. S. National Museum.

along the whole length of the plate from below and on the side opposite the coating. When the liquid has ceased to run, the plate is dried in the dark. The coating being well dried it is to be placed in the camera obscura. The time required to procure a photographic copy of a landscape is from seven to eight hours, but single monuments strongly illuminated by the sun or very bright in themselves are copied in about three hours.

When operating on glass it is necessary, in order to increase the light, to place the plate upon a piece of paper, with great care that the connection is perfect over every part, as otherwise confusion is produced in the design by imperfect reflection.

It frequently happens that when the plate is removed from the camera there is no trace of any image upon its surface. It is therefore necessary to use another process to bring out the hidden design.

To do this, provide a tin vessel larger than the tablet, having all around a ledge or border 50 mm. (2 English inches) in depth. Let this be three-fourths full of the oil of petroleum. Fix your tablet by the back to a piece of wood which completely covers the vessel and place it so that the tablet, face downwards, is over but not touching the oil. The vapor of the petroleum penetrates the coating of the plate in those parts on which the light has acted feebly—that is, in the portions which correspond to the shadows—imparting to them a transparency as if nothing were there. On the contrary, the points of the resinous coating on which light has acted, having been rendered impervious to the vapor, remain unchanged.

The design must be examined from time to time and withdrawn as soon as a vigorous effect is obtained. By urging the action too far even the strongest lights will be attacked by the vapor and disappear, to the destruction of the piece.

It may perhaps appear to some that I have needlessly given the particulars of a process, now superseded by others, possessing the most infinite sensibility, producing in a few minutes a better effect than was obtained by the heliographic process in several hours. There are, however, so many curious facts connected with the action of light on these resins that no treatise on photography could be considered complete without some description of them; and this process is now revived with a view to the production of etchings directly from nature.

M. Daguerre remarks that numerous experiments tried by him with these resinous preparations of M. Niepce prove that light can not fall upon a body without leaving traces of decomposition; and they also demonstrate that these bodies possess the power of renewing in darkness what has been lost by luminous action, provided total decomposition has not been effected. This heliographic process must be regarded as the earliest successful attempt at fixing on solid tablets the images of the camera obscura and at developing a dormant image.

B. Talbot's Photogenic Drawings.

On the 31st of January, 1839, six months prior to the publication of M. Daguerre's process, Mr. Fox Talbot communicated to the Royal Society his photographic discoveries, and in February he gave to the

world an account of the process he had devised for preparing a sensitive paper for photographic drawings. In the memoir read before the Royal Society he states:

> In the spring of 1834 I began to put in practice a method which I had devised some time previously for employing to purposes of utility the very curious property which has been long known to chemists to be possessed by nitrate of silver, namely, its discoloration when exposed to the violet rays of light.[a]

From this it appears that the English philosopher had pursued his researches ignorant of what had been done by others on the Continent. It is not necessary to enlarge in this place on the merits of the two discoveries of Talbot and Daguerre, but it may be well to show the kind of sensitiveness to which Mr. Talbot had arrived at this early period in his preparations, which will be best done by a brief extract from his own communication.

"It is so natural," says this experimentalist, "to associate the idea of labor with great complexity and elaborate detail of execution that one is struck more at seeing the thousand florets of an agrostis depicted with all its capillary branchlets (and so accurately that none of all this multitude shall want its little bivalve calyx, requiring to be examined through a lens), than one is by the large and simple leaf of an oak or a chestnut. But in truth the difficulty is in both cases the same. The one of these takes no more time to execute than the other; for the object which would take the most skilful artist days or weeks of labor to trace or to copy is affected by the boundless powers of natural chemistry in the space of a few seconds." And again, "to give some more definite idea of the rapidity of the process, I will state that after various trials the nearest valuation which I could make of the time necessary for obtaining the picture of an object so as to have pretty distinct outlines, when I employed the full sunshine, was half a second." This is to be understood of the paper then used by Mr. Talbot for taking objects by means of the solar microscope.

In the Philosophical Magazine, Mr. Fox Talbot published the first account of his photogenic experiments. The term was introduced by this gentleman, and his experiments can not be better described than in his own words:

> In order to make what may be called ordinary photogenic paper, I select, in the first place, paper of a good firm quality and smooth surface. I do not know that anything answers better than superfine writing paper. I dip it into a weak solution of common salt and wipe it dry, by which the salt is uniformly distributed throughout its substance. I then spread the solution of nitrate of silver on one surface only, and dry it at the fire. The solution should not be saturated, but six or eight times diluted with water. When dry the paper is fit for use.
>
> I have found by experiment that there is a certain proportion between the

[a] He no doubt means the chloride.—T. W. S.

quantity of salt and that of the solution of silver which answers best and gives the maximum effect. If the strength of the salt is augmented beyond this point the effect diminishes, and, in certain cases, becomes exceedingly small.

This paper, if properly made, is very useful for all photographic purposes. For example, nothing can be more perfect than the images it gives of leaves and flowers, especially with a summer sun, the light passing through the leaves delineates every ramification of their nerves.

Now, suppose we take a sheet thus prepared and wash it with a saturated solution of salt and then dry it. We shall find (especially if the paper is kept some weeks before trial is made) that its sensibility is greatly diminished, and in some cases seems quite extinct. But if it is again washed with a liberal quantity of the solution of silver, it becomes again sensible to light, and even more so than it was at first. In this way, by alternately washing the paper with salt and silver, and drying it between times, I have succeeded in increasing its sensibility to the degree that is requsite for receiving the images of the camera obscura.

In conducting this operation it will be found that the results are sometimes more and sometimes less satisfactory in consequence of small and accidental variations in the proportions employed. It happens sometimes that the chloride of silver is disposed to draken of itself without any exposure to light. This shows that the attempt to give it sensibility has been carried too far. The object is to approach to this condition as near as possible without reaching it, so that the substance may be in a state ready to yield to the slightest extraneous force, such as the feeble impact of the violet rays when much attenuated. Having, therefore, prepared a number of sheets of paper with chemical proportions slightly different from one another, let a piece be cut from each, and, having been duly marked or numbered, let them be placed side by side in a very weak diffused light for a quarter of an hour. Then, if any one of them, as frequently happens, exhibits a marked advantage over its competitors, I select the paper which bears the corresponding number to be placed in the camera obscura.

The increased sensitiveness given to paper by alternate ablutions of saline and argentine washes, the striking differences of effect produced by accidental variations of the proportions in which the chemical ingredients are applied, and the spontaneous change which takes place, even in the dark, on the more sensitive varieties of the paper, are all subjects of great interest, which demand further investigation than they have ever yet received, and which, if followed out, promise some most important explanations of chemcial phenomena at present involved in uncertainty, particularly those which appear to show the influence of time, an element not sufficiently taken into account, in overcoming the weaker affinities. Few fields of research promise a greater measure of reward than these. Already the art of making sun pictures has led to many very important physical discoveries, but most of the phenomena are yet involved in obscurity.

C. Daguerreotype—The Discovery of M. Daguerre.

It has already been stated that Niepce and Daguerre, having by accident discovered they were prosecuting experiments of the same kind, entered into partnership. On the 5th of December, 1829,

Niepce communicated to Daguerre the particulars of the process employed by him, which has been already described (Chap. II) under the term "heliography." Niepce died in July, 1833, but he has left some letters which clearly show that he had been a most industrious investigator. One extract appears of particular importance. "I repeat it, sir," he says, "I do not see that we can hope to derive any advantage from this process (the use of iodine) more than from any other method which depends upon the use of metallic oxides," etc. Again, he says, "a decoction of Thlaspi (Shepherd's purse), fumes of phosphorus, and particularly of sulphur, as acting on silver in the same way as iodine, and caloric, produce the same effects by oxidizing the metal, for from this cause proceeded in all these instances their extreme sensibilitly to light. After the death of M. Nicephore Niepce a new agreement was entered into between his son, M. Isidore Niepce, and Daguerre that they should pursue their investigations, in common and share the profits, whatever they might eventually prove to be.

The discovery of Daguerre was reported to the world early in January, 1839, but the process by which his beautiful pictures were produced was not made known until the July following, after a bill was passed securing to himself a pension for life of 6,000 francs, and to M. Isidore Niepce, the son of Monsieur Niepce above mentioned, a pension for life of 4,000 francs, with one-half in reversion to their widows. It was regretted that after the French Government had thus liberally purchased the secret of the process of the daguerreotype for "the glory of endowing the world of science and art with one of the most surprising discoveries that honor their native land," on the argument that "the invention did not admit of being secured by patent, for as soon as published all might avail themselves of its advantages," that its author should have guarded it by a patent right in England.

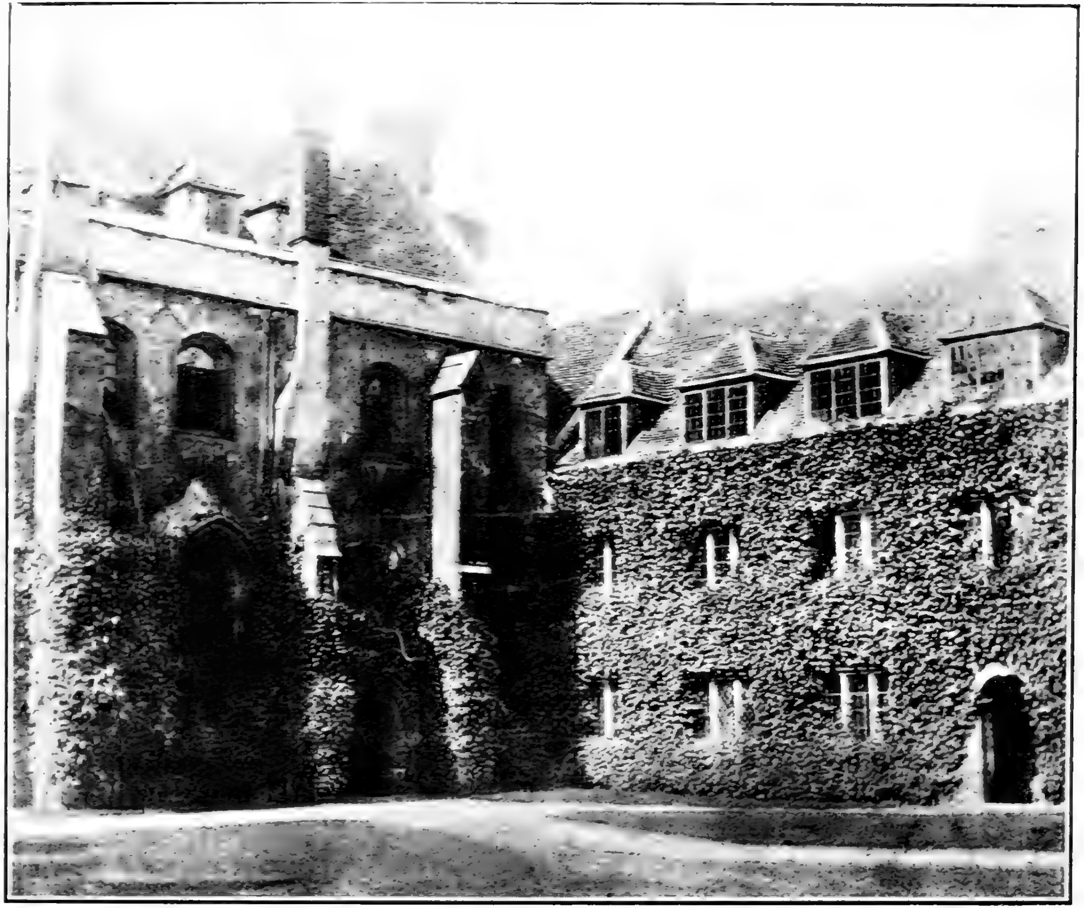
From the primary importance of this very beautiful branch of the photographic art I shall devote some space to a description of the original process, reserving for the division devoted to the manipulatory details the description of each improvement which has been published having any practical advantage, either by lessening the labor required or reducing the expense.

The pictures of the daguerreotype are executed upon thin sheets of silver plated on copper. Although the copper serves principally to support the silver foil, the combination of the two metals appears to tend to the perfection of the effect. It is essential that the silver should be very pure. The thickness of the copper should be sufficient to maintain perfect flatness and a smooth surface, so that the images may not be distorted by any warping or unevenness. Unnecessary thickness is to be avoided on account of the weight.

The process is divided by Daguerre into five operations. The first

H. FOX TALBOT.

From original in U. S. National Museum.



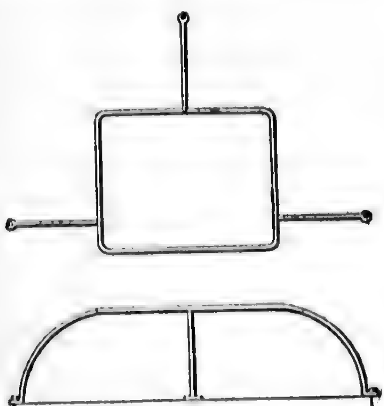
PEMBROKE COLLEGE, OXFORD.

From a talbotype sent by H. Fox Talbot to Langenheim Brothers as an example of his process. Original in U. S. National Museum.

consists in cleaning and polishing the plate to fit it for receiving the sensitive coating on which the light forms the picture. The second is the formation of the sensitive ioduret of silver over the face of the tablet. The third is the adjusting of the plate in the camera obscura for the purpose of receiving the impression. The fourth is the bringing out of the photographic picture, which is invisible when the plate is taken from the camera. The fifth and last operation is to remove the sensitive coating, and thus prevent that susceptibility of change under luminous influence which would otherwise exist and quickly destroy the picture.

First operation.—A small phial of olive oil, some finely carded cotton, a muslin bag of finely levigated pumice, a phial of nitric acid, diluted in the proportion of 1 part of acid to 16 parts of water, are required for this operation. The operator must also provide himself with a small spirit lamp and an iron-wire frame, upon which the plate is to be placed while being heated over the lamp.

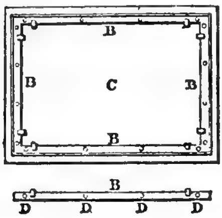
The plate being first powdered over with pumice, by shaking the bag, a piece of cotton dipped into the olive oil is then carefully rubbed over it with a continuous circular motion, commencing from the center. When the plate is well polished, it must be cleaned by powdering it well over with pumice and then rubbing it with dry cotton, always rounding and crossing the strokes, it being impossible to obtain a true surface by any other motion of the hand. The surface of the plate is now rubbed all over with a pledget of cotton, slightly wetted with the diluted nitric acid. Frequently change the cotton and keep rubbing briskly that the acid may be equally diffused over the silver, as, if it is permitted to run into drops, it stains the table. It will be seen when the acid has been properly diffused from the appearance of a thin film equally spread over the surface. It is then to be cleaned off with a little pumice and dry cotton.



2.

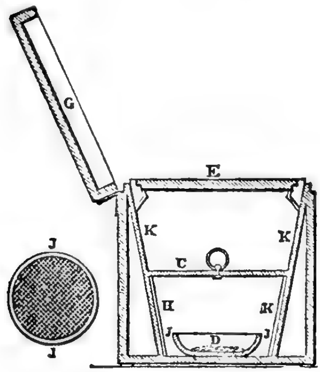
The plate is now placed on the wire frame, the silver upward, and the spirit lamp held in the hand and moved about below it, so that the flame plays upon the copper. This is continued for five minutes, when a white coating is formed all over the surface of the silver; the lamp is then withdrawn. A charcoal fire may be used instead of the lamp. The plate is now cooled suddenly by placing it on a mass of metal or a stone floor. When perfectly cold it is again polished with dry cotton and pumice. It is necessary that acid be

again applied two or three times in the manner before directed, the dry pumice being powdered over the plate each time and polished off gently with dry cotton. Care must be taken not to breathe upon the plate or touch it with the fingers, for the slightest stain upon the surface will be a defect in the drawing. It is indispensable that the last operation with the acid be performed immediately before it is intended for use. Let every particle of dust be removed by cleaning all the edges, and the back also, with cotton. After the first polishing the plate C is fixed on a board by means of four fillets, B B B B, of plated copper. (Fig. 3.) To each of these are soldered two small projecting pieces, which hold the tablet near the corners; and the whole is retained in a proper position by means of screws, as represented at D D D D.



3.

Second operation.—It is necessary for this operation, which is



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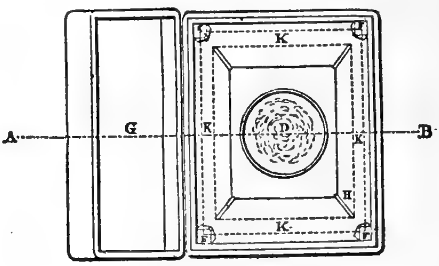


5.

really the most important of all, that a box similar to figures 4 and 5 be provided. Figure 4 represents a section supposed to pass down the middle of the apparatus by the line A B in figure 5, which represents the box as seen from above. C is a small lid which accurately fits the interior and divides the boxes into two chambers. It is kept constantly in its place when the box is not in use, the purpose of it being to concentrate the vapor of the iodine that it may act more readily upon the plate when it is exposed to it. D is the little capsule in which the iodine is placed, which is covered with the ring J, upon which is stretched a piece of fine gauze, by which the particles of iodine are prevented from rising and staining the plate, while the vapor, of course, passes freely through it. E is the board with the plate attached, which rests on the four smaller projecting pieces F,

figure 5. G is the lid of the box, which is kept closed, except when the plate is removed or inserted. H represents the supports for the cover C; K K, tapering sides all round, forming a funnel-shaped box within.

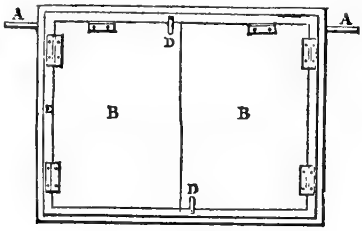
To prepare the plate: The cover C being taken out, the cup D is charged with a sufficient quantity of iodine, broken into small pieces, and covered with the gauze J. The board E is now, with the plate attached, placed face downward in its proper position and the box carefully closed.

In this position the plate remains until the vapor of the iodine has produced a definite golden-yellow color—nothing more or less. If the operation is prolonged beyond the point at which this effect is produced, a violet color is assumed, which is much less sensitive to light, and if the yellow coating is too pale the picture produced will prove very faint in all its parts. The time for this can not be fixed, as it depends entirely on the temperature of the surrounding air. No artificial heat must be applied, unless in the case of elevating the temperature of an apartment in which the operation may be going on. It is also important that the temperature of the inside of the box should be the same as it is without, as otherwise a deposition of moisture is liable to take place over the surface of the plate. It is well to leave a portion of the iodine always in the box, for, as it is slowly vaporized, it is absorbed by the wood, and when required it is given out over the more extended surface more equally and with greater rapidity.

As, according to the season of the year, the time for producing the required effect may vary from five minutes to half an hour or more, it is necessary, from time to time, to inspect the plate. This is also necessary to see if the iodine is acting equally on every part of the silver, as it sometimes happens that the color is sooner produced on one side than on the other, and the plate, when such is the case, must be turned one quarter round. The plate must be inspected in a darkened room, to which a faint light is admitted in some indirect way, as by a door a little open. The board being lifted from the box with both hands, the operator turning the plate toward him rapidly, observes the color. If too pale, it must be returned to the box; but if it has assumed the violet color it is useless, and the whole process must be again gone through.

From description, this operation may appear very difficult, but with a little practice the precise interval necessary to produce the best effect is pretty easily guessed at. When the proper yellow color is produced, the plate must be put into a frame, which fits the camera obscura, and the doors are instantly closed upon it to prevent the

access of light. The figures represent this frame, figure 6, with the doors, B B, closed on the plate, and figure 7 with the doors opened by the half circles A A. D D are stops by which the doors are fastened until the moment when the plate is required for use. The third



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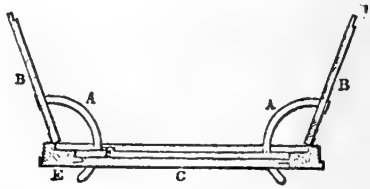
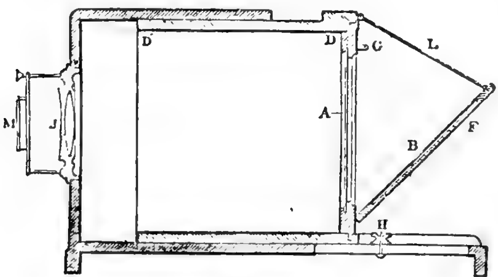


7.

operation should, if possible, immediately succeed the second. The longest interval between them should not exceed an hour, as the iodine and silver lose their requisite photogenic properties.[a] It is necessary to observe that the iodine ought never to be touched with the fingers, as we are very liable to injure the plate by touching it with the hands thus stained.

Third operation.—The third operation is the fixing of the plate at the proper focal distance from the lens of the camera obscura and placing the camera itself in the right position for taking the view we desire. Figure 8 is a perpendicular section, lengthwise, of Daguerre's camera. A is a ground glass by which the focus is adjusted. It is then removed and the photographic plate substituted, as in C (fig. 9). B is a mirror for observing the effects of objects and selecting the best points of view. It is inclined at an angle of 45° by means of the support L. To adjust the focus, the mirror is lowered and the piece of ground glass, A, used. The focus is easily adjusted by sliding the box D out or in, as represented in the plate. When the focus is adjusted, it is retained in its place by means of the screw H. The object glass J is achromatic and periscopic. Its diameter is about 1 inch, and its focal distance rather more than 14 inches. M is a stop



8.

[a] This is contrary to the experience of the author of this volume, and Doctor Draper, of New York, states that he has found the plates improve by keeping a few hours before they are used, and M. Claudet states that even after a day or two the sensibility of the plates is not impaired.

L. J. M. DAGUERRE.

From original daguerreotype by Meade Brothers, deposited in the U. S. National Museum by Mrs. Sarah M. M. Valentine.

FIG. 1.—NIEPCE'S APPARATUS.

From "Photominiature."

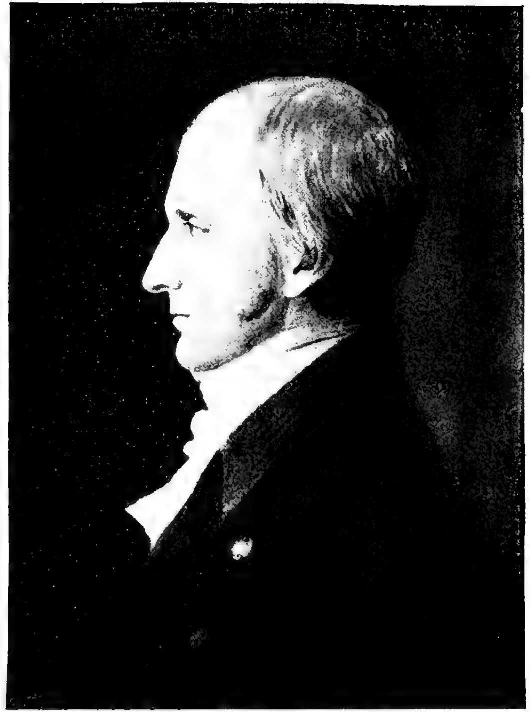
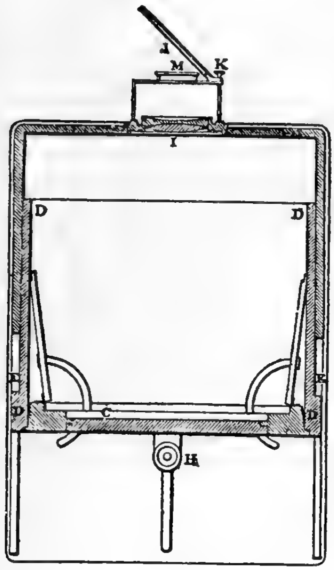


FIG. 2.—THOMAS WEDGEWOOD.

From "Photominiature," originally published in "Photography," 1902.

a short distance from the lens, the object of which is to cut off all those rays of light which do not come directly from the object to which the camera is directed. This instrument reverses the objects, that which is to the right in nature being to the left in the photograph. This can be remedied by using a mirror outside, as K J, in figure 9. This arrangement, however, reduces the quantity of light and increases the time of the operation one-third. It will, of course, be adopted only when there is time to spare.

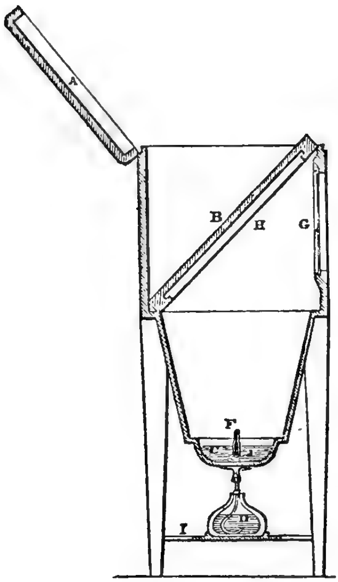


9.

After having placed the camera in front of the landscape or any object of which we desire the representation, our first attention must be to adjust the plate at such a distance from the lens that a neat and sharply defined picture is produced. This is, of course, done by the obscured glass. The adjustment being satisfactorily made the glass is removed and its place supplied by the frame containing the prepared plate, and the whole secured by screws. The doors are now opened by means of the half circles and the plate exposed to receive the picture. The length of time necessary for the production of the best effect, varying with the quantity of light, is a matter which requires the exercise of considerable judgment, particularly as no impression is visible upon the tablet when it is withdrawn from the camera. At Paris this varies from three to thirty minutes. The most favorable time is from 7 to 3 o'clock. A drawing which in the months of June and July may be taken in three or four minutes will require five or six in May or August, seven or eight in April or September, and so on, according to the season. Objects in shadow, even during the brightest weather, will require twenty minutes to be correctly delineated. From what has been stated it will be evident that it is impossible to fix with any precision the exact length of time necessary to obtain photographic designs, but by practice we soon learn to calculate the required time with considerable correctness. The latitude is, of course, a fixed element in this calculation. In the sunny climes of Italy and southern France these designs may be obtained much more promptly than in the uncertain climate of Great Britain. It is very important that the time necessary is not exceeded—prolonged solarization has the effect of blackening the

plate, and this destroys the clearness of the design. If the operator has failed in his first experiment, let him immediately commence with another plate; correcting the second trial by the first he will seldom fail to reproduce a good photograph.

Fourth operation.—The apparatus required in this operation is represented by figure 10. A is the lid of the box; B, a blackboard with grooves to receive the plate; C, cup containing a little mercury (J); D, spirit lamp; F, thermometer; G, glass through which to inspect the operation; H, tablet as removed from the camera; I, stand for the spirit lamp. All the interior of this apparatus should be covered with hard, black varnish. The board and the affixed plate being withdrawn from the camera are placed at an angle of about 45° within this box, the tablet with the picture downward, so that it may be seen through the glass G. The box being carefully closed, the spirit lamp is to be lighted and placed under the cup containing the mercury. The heat is to be applied until the thermometer, the bulb of which is covered with the mercury, indicates a temperature of 60° C. (140° F.). The lamp is then withdrawn, and if the thermometer has risen rapidly, it will continue to rise without the aid of the lamp, but the elevation ought not to be allowed to exceed 75° C. (167° F.).



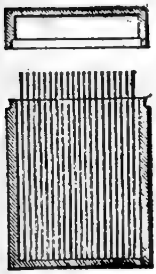
10.

After a few minutes the image of nature impressed, but now invisible, on the plate begins to appear. The operator assures himself of the progress of this development by examining the picture through the glass G, by a taper, taking care that the rays do not fall too strongly on the plate and injure the nascent images. The operation is continued till the thermometer sinks to 45° C. (113° F.). When the objects have been strongly illuminated, or when the plate has been kept in the camera too long, it will be found that this operation is completed before the thermometer has fallen to 55° C. (131° F.). This is, however, always known by observing the sketch through the glass.

After each operation the apparatus is carefully cleaned in every part, and in particular the strips of metal which hold the plate are well rubbed with pumice and water to remove the adhering

mercury and iodine. The plate may now be deposited in the grooved box (fig. 11), in which it may be kept, excluded from the light, until it is convenient to perform the last fixing operation.

Fifth operation.—This process has for its object the removal of the iodine from the plate of silver, which prevents the further action of the light.



11.

A saturated solution of common salt may be used for this purpose, but it does not answer nearly so well as a weak solution of the hyposulphite of soda. In the first place the plate is to be placed in a trough of water, plunging and withdrawing it immediately; it is then to be plunged into one of the above saline solutions, which would act upon the drawing if it was not previously hardened by washing in water.

To assist the effect of the saline washes, the plate must be moved to and fro, which is best done by passing a wire beneath the plate. When the yellow color has quite disappeared the plate is lifted out, great care being taken that the impression is not touched, and it is again plunged into water. A vessel of warm distilled water, or very pure rain water boiled and cooled, being provided, the plate is fixed on an inclined plane and the water is poured in a continuous stream over the picture. The drops of water which may remain upon the plate must be removed by forcibly blowing upon it, for otherwise, in drying, they would leave stains on the drawings. This finishes the drawing, and it only remains to preserve the silver from tarnishing and from dust.

The shadows in the daguerreotype pictures are represented by the polished surface of the silver, and the lights by the adhering mercury, which will not bear the slightest rubbing. To preserve these sketches they must be placed in cases of pasteboard with a glass cover over them and then framed in wood. They are now unalterable by the sun's light.

The same plate may be employed for many successive trials, provided the silver be not polished through to the copper. It is very important, after each trial, that the mercury be removed immediately by polishing with pumice powder and oil. If this be neglected the mercury finally adheres to the silver, and good drawings can not be obtained if this amalgam is present.

D. The Calotype.

Early in 1840 drawings on paper were handed about in the scientific circles of London and of Paris, which were a great advance upon anything which had been previously done. These were the results of a new process discovered by Mr. Talbot, and then attracted so much attention that Monsieur Biot made them the subject

of a communication to the Academy of Sciences in Paris. His remarks were printed in extenso in the Comptes Rendus.

Mr. Talbot's description of his process, the patent for which is dated 1841, is as follows:[a]

Take a sheet of the best writing paper, having a smooth surface and a close and even texture. The watermark, if any, should be cut off lest it should injure the appearance of the picture. Dissolve 100 grains of crystallized nitrate of silver in 6 ounces of distilled water. Wash the paper with this solution with a soft brush on one side, and put a mark on that side, whereby to know it again. Dry the paper cautiously at a distance from the fire, or else let it dry spontaneously in a dark room. When dry, or nearly so, dip it into a solution of iodide of potassium, containing 500 grains of that salt dissolved in one pint of water, and let it stay two or three minutes in the solution. Then dip the paper into a vessel of water, dry it lightly with blotting paper, and finish drying it at a fire, which will not injure it even if held pretty near; or else it may be left to dry spontaneously. All this is best done in the evening by candlelight. The paper, so far prepared, is called iodized paper, because it has a uniform pale-yellow coating of iodide of silver. It is scarcely sensitive to light, but nevertheless it ought to be kept in a portfolio or drawer until wanted for use. It may be kept for any length of time without spoiling or undergoing any change, if protected from sunshine. When the paper is required for use take a sheet of it and wash it with a liquid prepared in the following manner:

Dissolve 100 grains of crystallized nitrate of silver in 2 ounces of distilled water; add to this solution one-sixth of its volume of strong acetic acid. Let this be called mixture A.

Make a saturated solution of crystallized gallic acid in cold distilled water. The quantity dissolved is very small. Call this solution B.

Mix together the liquids A and B in equal volumes, but only a small quantity of them at a time, because the mixture does not keep long without spoiling. This mixture Mr. Talbot calls the gallo-nitrate of silver. This solution must be washed over the iodized paper on the side marked, and being allowed to remain upon it for half a minute, it must be dipped into water, and then lightly dried with blotting paper. This operation in particular requires the exclusion of daylight; and although the paper thus prepared has been found to keep for two or three months, it is advisable to use it within a few hours, as it is often rendered useless by spontaneous change in the dark.

[a] Mr. Talbot, by a letter in the Times of August 13, 1852, gives to the public the right of using any of his patents for any purpose not involving the production of portraits from life.

FIG. 1.—TALBOT'S STUDIO.

FIG. 2.—CALOTYPE PRINTING OUTFIT.

From "Photominiature."

Paper thus prepared is exquisitely sensitive to light, an exposure of less than a second to diffused daylight being quite sufficient to set up the process of change. If a piece of this paper is partly covered and the other exposed to daylight for the briefest possible period of time, a very decided impression will be made. This impression is latent and invisible. If, however, the paper be placed aside in the dark, it will gradually develop itself; or it may be brought out immediately by being washed over with the gallo-nitrate of silver, and held at a short distance from the fire, by which the exposed portions become brown, the covered parts remaining of their original color. The pictures being thus procured, are to be fixed by washing in clean water and lightly drying between blotting paper, after which they are to be washed over with a solution of bromide of potassium containing 100 grains of that salt dissolved in 8 or 10 ounces of water; after a minute or two it is again to be dipped into water, and then finally dried.

Such was, in all its main features, the description given by Mr. Talbot in his specification of his process for producing the calotype, or beautiful picture (as the term signifies). He, in a second patent, included the points stated in the next section.

SECTION III. IMPROVEMENTS IN CALOTYPE.

Such is the term employed by Mr. Talbot, and these improvements consist of the following particulars, constituting that gentleman's second claim:

1. Removing the yellowish tint which is occasioned by the iodide of silver from the paper by plunging it into a hot bath of hyposulphite of soda dissolved in ten times its weight of water and heated nearly to the boiling point. The picture should remain in the bath about ten minutes and be then washed in warm water and dried.

Although this has been included by Mr. Talbot in his specification, he has clearly no claim to it, since in February, 1840, Sir John Herschel published, in his memoir "On the chemical action of the rays of the solar spectrum," a process of fixing with the hot hyposulphite of soda.

After undergoing the operation of fixing the picture is placed upon a hot iron and wax melted into the pores of the paper to increase its transparency.

2. The calotype paper is rendered more sensitive by placing a warm iron behind in the camera while the light is acting upon it.

3. The preparation of io-gallic paper, which is simply washing a sheet of iodized paper with gallic acid. In this state it will keep in a portfolio, and is rendered sensitive to light by washing it over with a solution of nitrate of silver.

4. Iodized paper is washed with a mixture of 26 parts of saturated

solution of gallic acid to 1 part of the solution of nitrate of sulver ordinarily used. It can then be dried without fear of spoiling, may be kept a little time, and used without further preparation.

5. The improvement of photographic drawings by exposing them twice the usual time to the action of sunlight. The shadows are thus rendered too dark and the lights are not sufficiently white. The drawing is then washed and plunged into a bath of iodide of potassium of the strength of 500 grains to each pint of water and allowed to remain in it for one or two minutes, which makes the pictures brighter and its lights assume a pale-yellow tint. After this it is washed and immersed in a hot bath of hyposulphite of soda until the pale-yellow tint is removed and the lights remain quite white. The pictures thus finished have a pleasing and peculiar effect.

6. The appearance of photographic pictures is improved by waxing them and placing white or colored paper behind them.

7. Enlarged copies of daguerreotypes and calotypes can be obtained by throwing magnified images of them, by means of lenses, upon calotype paper.

8. Photographic printing. A few pages of letterpress are printed on one side only of a sheet of paper, which is waxed if thought necessary, and the letters are cut out and sorted; then, in order to compose a new page, a sheet of white paper is ruled with straight lines and the words are formed by cementing the separate letters in their proper order along the lines. A negative photographic copy is then taken, having white letters on a black ground; this is fixed, and any number of positive copies can be obtained. Another method proposed by the patentee is to take a copy by the camera obscura from large letters painted on a white board.

9. Photographic publication. This claim of the patentee consists in making, first, good negative drawings on papers prepared with salt and ammonio-nitrate of silver; secondly, fixing them by the process above described; thirdly, the formation of positive drawings from the negative copy, and fixing.

These claims, taken from the specification as published in the Repertory of Patent Inventions, are preserved in their original form for the purpose of showing how much that is now fully accomplished was foreseen by Mr. Talbot as the result of his discoveries.

SECTION IV. PICTURES ON PORCELAIN TABLETS.

A third patent has been obtained by Mr. Talbot, mainly involving the use of porcelain as a substitute for glass, and contains some useful facts noticed by Mr. Malone.

The first part of the patentee's invention consists in the use of plates of unglazed porcelain to receive the photographic image. A plate intended for photographic purposes should be made of the finest

materials employed by the manufacturers of porcelain; it should also be flat, very thin, and semitransparent; if too thin, so that there would be a chance of breaking, it may be attached by means of cement to a piece of glass to give it strength. The substance of the plate should be slightly porous, so as to enable it to imbibe and retain a sufficient quantity of the chemical solutions employed. To prepare the plate for use, it is first required to give it a coating of albumen, or white of eggs, laid on very evenly, and then gently dried at a fire. According as the plate is more or less porous, it requires more or less of the albuminous coating; it is best to employ a very close-grained porcelain, which requires but little white of egg. The prepared plate may be made sensitive to light in the same way in which a sheet of paper is rendered sensitive; and we generally find the same methods applicable for photographic pictures on paper applicable to those on porcelain plates, and one of the processes employed by the patentee is nearly the same as that patented by Mr. Talbot in 1841.

The prepared plate is dipped into a solution of nitrate of silver made by dissolving 25 grains of nitrate in 1 ounce of water; or the solution is spread over the plate uniformly with a brush. The plate is then dried, afterwards dipped into a solution of iodide of potassium of the strength of about 25 grains of iodide to 1 ounce of water, again dried, and the surface rubbed clean and smooth with cotton. The plate is now of a pale-yellow color, owing to the formation on the surface of iodide of silver. The plate, prepared as above directed, may be kept in this state until required, when it is to be rendered sensitive to light by washing it over with a solution of gallo-nitrate of silver, then placed in the camera; and the image obtained is to be rendered visible and sufficiently strengthened by another washing of the same liquid, aided by gentle warmth. The negative picture thus obtained is fixed by washing it with water, then with bromide of potassium, or, what is still better, hyposulphite of soda, and again several times in water. The plate of porcelain being semi-transparent, positive pictures can be obtained from the above-mentioned negative ones by copying them in a copying frame.

The picture obtained on porcelain can be altered or modified in appearance by the application of a strong heat, a process not applicable to pictures taken on paper. With respect to this part of their invention, the patentees claim:

> The obtaining by means of a camera or copying frame photographic images or pictures upon slabs or plates of porcelain.

The second part relates to the process which has been discovered and improved upon by Mr. Malone, who is associated with Mr. Fox Talbot in the patent. The patentees' improvement is a method of obtaining more complete fixation of photographic pictures on paper.

For this purpose the print, after undergoing the usual fixing process, is dipped into a boiling solution of strong caustic potash, which changes the color of the print, and usually, after a certain time, acquires something of a greenish tint, which indicates that the process is terminated.

The picture is then well washed and dried, and if the tint acquired by it is not pleasing to the eye a slight exposure to the vapors of sulphureted hydrogen will restore to it an agreeable brown or sepia tint. Under this treatment the picture diminishes in size, insomuch that if it were previously cut in two and one part submitted to the potash process and the other not, the two halves when afterwards put together would be found not to correspond. The advantages of this process for removing any iodine which, even after fixing with the hyposulphite, remains in the paper is great, and it will tend much to preserve these beautiful transcripts of nature.

The patentee also claims as an improvement on the use of varnished or other transparent paper impervious to water, as a substitute for glass in certain circumstances, to support a film of albumen for photographic purposes. A sheet of writing paper is brushed over with several coats of varnish on each side; it thus becomes extremely transparent. It is then brushed over on one side with albumen, or a mixture of albumen and gelatin and dried. This film of albumen is capable of being rendered sensitive to light by exposing it to the vapour of iodine, and by following the process indicated in the preceding section of this specification. The advantages of using varnished or oil paper do not consist in any superiority of the images over those obtained upon glass, but in the greater convenience of using paper than glass in cases where a large number of pictures have to be made and carried about for considerable distances; besides this, there is a well-known kind of photographic pictures giving panoramic views of scenery which are produced upon a curved surface by a movement of the object glass of the camera. To the production of these images glass is hardly applicable, since it can not be readily bent to the required curve and again straightened; but the case is met by employing talc, varnished paper, oiled paper, etc., instead of glass. It will be seen that the varnished paper acts as a support to the film of albumen or gelatin, which is the surface on which the light acts and forms the picture. The next improvement consists in forming photographic pictures or images on the surfaces of polished steel plates. For this purpose one part (by measure) of a standard solution of iodide of potassium is mixed with 200 parts of albumen, and spread as evenly as possible upon the surface of a steel plate and dried by the heat of a gentle fire. The plate is then taken, and, while still warm, is washed over with an alcoholic solution of gallo-nitrate of silver of moderate

strength. It then becomes very sensitive and easily receives a photographic image. If the plate be cold, the sensibility is considerably lower. The image obtained is fixed by washing with hyposulphate of soda and finally with water.

SECTION V. INSTANTANEOUS PROCESS.

The next invention and patent of Mr. Fox Talbot possesses many peculiarities, and as the results are of a remarkable character it is important that the process should be given uncurtailed in its main particulars. The following description must be regarded as an abstract of Mr. Talbot's communication to the Athenæum December 6, 1851. An experiment was tried in June, at the Royal Institution, in which an instantaneous image was produced; but as the process was the subject of another patent it was not published until the above date. The experiment in question was that of obtaining a photographic copy of a printed paper fastened to a wheel, which was made to revolve as rapidly as possible, by illuminating it for a moment by the light obtained from the discharge of a Leyden battery. The bill was faithfully printed, not even a letter being indistinct.

A glass plate is employed, and Mr. Talbot thus directs that it should be prepared:

1. Take the most liquid portion of the white of an egg, rejecting the rest. Mix it with an equal quantity of water. Spread it very evenly upon a plate of glass, and dry it at the fire. A strong heat may be used without injuring the plate. The film of dried albumen ought to be uniform and nearly invisible.

2. To an aqueous solution of nitrate of silver add a considerable quantity of alcohol, so that an ounce of the mixture may contain 3 grains of the nitrate. I have tried various proportions, from 1 to 6 grains, but perhaps 3 grains answer the best. More experiments are here required, since the results are much influenced by this part of the process.

3. Dip the plate into this solution, and then let it dry spontaneously. Faint prismatic colors will then be seen upon the plate. It is important to remark that the nitrate of silver appears to form a true chemical combination with the albumen, rendering it much harder and insoluble in liquids which dissolved it previously.

4. Wash with distilled water to remove any superfluous portion of the nitrate of silver. Then give the plate a second coating of albumen, similar to the first, but in drying avoid heating it too much, which would cause a commencement of decomposition of the silver.

5. To an aqueous solution of proto-iodide of iron add, first, an equal volume of acetic acid, and then 10 volumes of alcohol. Allow the mixture to repose two or three days. At the end of that time

it will have changed color, and the odor of acetic acid, as well as that of alcohol, will have disappeared, and the liquid will have acquired a peculiar but agreeable vinous odor. It is in this state that I prefer to employ it.

6. Into the iodide thus prepared and modified the plate is dipped for a few seconds. All these operations may be performed by moderate daylight, avoiding, however, the direct solar rays.

7. A solution is made of nitrate of silver, containing about 70 grains to 1 ounce of water. To 3 parts of this add 2 of acetic acid. Then, if the prepared plate is rapidly dipped once or twice into this solution, it acquires a very great degree of sensibility, and it ought then to be placed in the camera without much delay.

8. The plate is withdrawn from the camera, and in order to bring out the image it is dipped into a solution of protosulphate of iron containing 1 part of the saturated solution diluted with 2 or 3 parts of water. The image appears very rapidly.

9. Having washed the plate with water, it is now placed in a solution of hyposulphite of soda, which in one minute causes the image to brighten up exceedingly by removing a kind of veil which previously covered it.

10. The plate is then washed with distilled water and the process is terminated. In order, however, to guard against future accidents it is well to give the picture another coating of albumen and varnish.

These operations may appear long in the description, but they are rapidly enough executed after a little practice. In the process which I have now described I trust that I have effected a harmonious combination of several previously ascertained and valuable facts, especially of the photographic property of iodide of iron, which was discovered by Doctor Woods, of Parsontown, in Ireland; and that of sulphate of iron, for which science is indebted to the researches of Mr. Robert Hunt. In the true adjustment of the proportions and in the mode of operation lies the difficulty of these investigations, since it is possible by adopting other proportions and manipulations not very greatly differing from the above, and which a careless reader might consider to be the same, not only to fail in obtaining the highly exalted sensibility which is desirable in this process, but actually to obtain scarcely any photographic result at all.

Mr. Talbot proposed the name of "amphitype," or doubtful image for these pictures. This name had, however, been adopted previously, at Mr. Talbot's recommendation, by Sir John Herschel, and in the collodion processes, to be by and by described, we have similar phenomena, to which the name applies with equal force.

It is not improbable that the high degree of sensibility which is certainly obtained in this process is rather due to the formation of an iodide of ethyl in the mixture than to the combination, as Mr. Talbot supposes, of the proto-iodide and the proto-sulphate of iron. My own researches convince me that we should seek for the highest degrees of sensibility amidst the numerous combinations of the ethyl and methyl compounds with the metallic oxides.

THEORIES OF ORE DEPOSITION HISTORICALLY CONSIDERED.

By S. F. Emmons.[a]

In the city in which we meet this year an exposition is preparing which is designed to commemorate the peaceful acquirement a century ago of the rights of France to the Mississippi Valley and the regions to the west. It was the metallic wealth of the valley region which first led to its exploration by the French, and which still constitutes an important feature in its industry, yielding annually, as it does, an amount about equal to the original purchase price. To a still greater degree has the unexampled rapidity with which, in the last half century, civilization and industry have spread over the mountainous regions of the West been due to the development of their mineral resources—a development to which geological science has in no small measure contributed.

In selecting a subject for my address as president of the Geological Society of America it has seemed appropriate, therefore, both to the time and to the place, to choose a theme that has to do with that branch of geology which is especially concerned with the deposits of the metals. The history of theories of ore deposition was the subject originally chosen, but, as it gradually developed in the course of research, it was found that anything worthy of that name would far exceed the proper limits of an address. Thus its scope has been gradually narrowed to fit the necessities of the occasion, until it has become little more than a brief enumeration of the opinions held from time to time within the historic period which seems to have left the most permanent impress upon the minds of geologists.

The term "ore deposition," which is used in preference to its earlier synonym "vein formation" as more correctly representing the broader conceptions of the present day, applies, it is hardly

[a] Annual address by the president of the Geological Society of America, read before the society at St. Louis, Mo., December 30, 1903. Reprinted from author's revised copy.

necessary to state, only to the processes involved in the formation of deposits that form an integral part of the rock in which they occur, or "rock in place," as is the legal phraseology of the day, and does not include such recent detrital deposits as placers, etc., about whose origin there has never been any wide divergence of opinion.

PREHISTORICAL VIEWS.

The historic period is assumed to have been entered on only with the revival of learning about the time of the Reformation at the commencement of the sixteenth century. What few records can be found of genetic opinions held before that time, even as to the more striking and readily observable geological phenomena, such as volcanic eruptions, earthquakes, and changes in the earth's surface, are too scattered and fragmentary to afford evidence of any continuous development of thought. The views of the Pythagorean and Aristotelian schools of philosophy on the causes of these natural phenomena, though apparently based more on bold poetical fantasy than exact observation, present a clearer and more logical conception than that which obtained nearly twenty centuries later. Thus it is said that as early as 600 B. C. the observed occurrence in the rocks of casts of shells and plants were ascribed to periodical floodings of the land. During the Middle Ages, however, under the monkish influence that discouraged any views that might throw doubt on the literal correctness of the Mosaic cosmogony, these fossils were variously assumed to have been formed in place by the agencies of the stars, to have been transformed from rock by some plastic force (vis plastica), or left by the waters of the Noachian deluge.

Among the early cosmogonies, which it is true are of mythologic rather than of scientific interest, the Chinese is the only one which included metal among the elements of creation. Yet the general use of the metals, whose extraction from their native ores presupposes a knowledge of the art of smelting—in itself an evidence of a certain insight into nature's processes—goes back to very remote antiquity. It seems possible that the philosophers of these earlier civilizations may have indulged in speculations as to the origin of the metals, but if so they left no written record. Even among the Romans, of whose proficiency in mining evidence is found in most of the mining regions that came under their control, little or no genetic speculation was indulged in, if we accept the evidence of Pliny's Natural History. This monumental work, which is assumed to contain a complete and faithful presentation of the knowledge of natural phenomena at the opening of the Christian era, though it described in considerable detail the methods of mining then in vogue, does not

even attempt a description of the mode of occurrence of the ores, much less speculate on their origin.

The historic time here contemplated may be divided, in a general way, into three periods, according to the prevailing method by which the views then current were arrived at.

DEVELOPMENT OF KNOWLEDGE HISTORICALLY CONSIDERED.

THE THREE PERIODS.

1. The speculative period, in which, from a few rather imperfectly determined facts of nature, general theories were evolved intended to be applicable to all natural phenomena. It was a period in which geology was not yet recognized as a distinct science and had hardly reached the dignity of an adjunct to mineralogy.

2. The second period was that in which facts of observation had accumulated sufficiently to establish geology on the basis of a distinct science, but in which the method of reasoning from generals to particulars still prevailed. This was the first scientific period.

3. The third period might be called the period of verification, in which the theories already propounded were tested by experiment or observation.

Such a classification is in the nature of things not susceptible of a very definite demarcation either in point of time or in the assignment to either period of individual opinions or theories, but the attempt to make it, however imperfect and unsuccessful it may prove, will assist us to form a clearer conception of the progress of human thought and of the methods by which it has arrived at its present understanding of the particular branch of geological science which we are considering.

THE SPECULATIVE PERIOD.

During the first or speculative period, which may be assumed to have extended up to the close of the eighteenth century, or to the time of Werner and Hutton, the accumulation of accurately determined facts that would bear on the theory of ore deposits was so extremely limited that it may be assumed to have exercised but little influence on the development of the science beyond the suggestion it afforded to later students of lines of investigation to be followed, and hence may be passed over in a very cursory manner.

In the speculations of this period which especially influenced the development of opinion two general types may be distinguished:

First. The broader theories of the cosmic philosophers with regard to the formation of the earth, based more or less upon astronomic data.

Second. The special theories of mineral vein formation conceived by individuals and based in the main on general conceptions which

were supplemented by a certain amount of personal observation and experience.

The cosmic philosophers were men who, without being geologists in the modern sense of the word, nevertheless put forth ideas with regard to the system of the earth that had an undoubted influence on the minds of those who have since made a special study of this part of science.

First of these was Descartes, the French mathematician and founder of the Cartesian system of philosophy (Principia, 1644), who considered the earth a planet like the sun, but which, though cooled and consolidated at its surface, still preserved in its interior a central fire that caused the return toward the surface of waters of infiltration, the filling of veins by the metals, and the dislocations of the solid crust.

Nearly contemporary with him was Steno, a Danish physician, who spent the greater part of his life in Italy, where he devoted much of his time to the study of geological phenomena. He was the first to seek to learn the origin of rocks and the changes in the earth's crust by the inductive method. He wrote a remarkable treatise, bearing the quaint title "De Solido intra Solidum naturaliter Contento" (1669), in which he considers vein fissures to be later than the inclosing rocks and their filling to result from the condensation of vapors proceeding from the interior. Steno's ideas, so much in advance of those of his age, seem to have found little favor among his contemporaries, and were scarcely known among geologists until called to their attention in the first half of the nineteenth century by de Beaumont and von Humboldt.

Later Leibnitz, a German philosopher, inspired both by the ideas of Descartes and the observations and deductions of Steno, wrote a work on the origin of the earth (Protogæa, 1691), which, in spite of its necessarily limited basis of facts, bears the imprint of genius in its conceptions. In applying his theories to the veins of the Hartz, which he had occasion to visit during his thirty years' sojourn at Hanover, Leibnitz considers that they have been filled sometimes by the liquefying action of fire, sometimes by water.

In the following century Buffon, the great French philosopher, excited to the highest degree the attention of the scientific world by his Théorie de la Terre, 1749, and Époques de la Nature, 1778. His conceptions, though striking by the brilliancy of their imagination, have for the most part not proved of enduring value. Nevertheless they served a purpose by stimulating more exact observations on the points with regard to which his views were contested. With regard to mineral veins he held that they were primarily fissures opened in the mountains through the force of contraction, and that they were filled by metals which by long and constant heat had separated

from other vitrifiable materials. But as there are nonvitrifiable as well as vitrifiable materials in veins, so there are secondary veins which have been filled with nonvitrifiable minerals by the action of water. The primary veins he considers to be characteristic of high mountains, while the secondary veins occur rather at the foot of the mountains, and probably derived some of their material from the primary veins.

In the second class the foremost place, both in time and in the importance of his actual observations, must be accorded to Dr. George Bauer, better known by his Latinized name of Agricola, a German physician who flourished during the first half of the sixteenth century. He spent a great part of his life among the mines of Saxony (Joachimsthal), of which he made a careful study. He wrote in most excellent Latin several works on mineralogy and on the art of mining, which were for centuries standard books of reference on these subjects, and even to the present day contain much of interest to the mining engineer. Agricola was first and foremost a mineralogist, and all his work was characterized by acuteness of observation and accuracy of description, though in strong contrast to most of the early writers he did not indulge much in earth-formation theories. He divided mineral veins into "commissuræ" (joints or rents), "fibræ" (small branching veins), "venæ" (large veins or channels), and "terræ canales" (vein systems), and gives a clear account of their size, position, intersections, etc. In theoretical matters he was less definite and satisfactory.

During all this period the two main subjects of speculation with regard to mineral veins, which term practically included all ore deposits, were (1) their age relative to the rocks in which they were found, and (2) the cause and manner of their filling; and in considering the views put forward on these subjects we must bear in mind that chemistry as a science only came into existence toward the end of the eighteenth century, hence the ideas which were entertained as to the processes that may have gone on within the earth's crust to form metallic deposits were necessarily somewhat vague and fanciful.

Among the ideas current in his time Agricola, as a result of his observations, promptly rejected the views that veins were formed contemporaneously with the primary rocks of the globe and that the planets had an influence in the formation of the metals, but he seems to have had very few positive ideas of his own as to their origin, though inclining to ascribe vein filling to material brought in by circulating waters. He still entertained the idea of a lapidifying juice, which he conceived as giving to water the power of absorbing earth and of corroding metals, and which might have formed fossil casts as well as minerals. His use of the term "fossilia" for both minerals and petrifications, which was retained by subsequent

geological writers, especially those of the Wernerian school, is often a cause of misconception among modern readers who have occasion to consult the older works on geology and mineralogy.

For over a century after Agricola there appears to have been little written that had any special bearing on ore deposits, but toward the close of the seventeenth century there was an apparent awakening of interest in regard to their origin among reflective men who had to do directly or indirectly with mines, which may probably have been prompted by the theories of the cosmic philosophers, so that by the close of the eighteenth century there had accumulated considerable speculative literature on this subject.

The following is a list of the more frequently quoted works that appeared during this period, with the approximate dates of their publication:

Speculum Metallurgiæ politissimum, by Bergmeister Balthasar Rösler (1700).

Physica subterranea, by J. J. Becher. Commentated by G. S. Stahl. Second edition (1703).

Pyritologia, by J. F. Henkel, professor of chemistry and mineralogy, Freiberg (1725).

Obersächsiche Bergakademie, by C. F. Zimmermann, councilor of mines (1749).

Markscheidekunst, by Von Oppel, vice-director of Saxon mines (1749).

Abh. v. d. Metalmuttern, etc., by D. J. H. Lehman, director of Prussian mines (1753).

Elementa Metallurgiæ Chemicæ, by W. J. Wallerius, Stockholm (1768).

Ursprung d. Gebirge u. Erzadern, etc., by C. F. Delius, professor of metallurgy at Schemnitz (1770).

Mineral. Geograph. d. Kursächsische Lander, by J. F. W. de Charpentier, director of Saxon mines (1778).

Unterirdische Geographie, by I. G. Baumer, Giessen (1779).

Gesch. d. Metallreichs, by C. A. Gerhard, councilor of mines (1781).

Erfahr. ü. d. Innern d. Gebirge, by F. M. H. v. Trebra, vice-director of Hanoverian mines (1785).

Beobacht. ü. d. Hartz Gebirge, by Lieut. G. O. S. Lasius, engineer on land survey of Hanover (1787).

The views of most of these early writers were rather curious than instructive, yet some of them, especially those of men who had the largest practical experience in mines, are remarkably suggestive.

Rösler, the earliest recorded mine superintendent, recognized that veins differ from ordinary cracks in the rocks only by being filled with metallic minerals, but did not speculate on their genesis. Becher and his commentator, Stahl, both professors of medicine, assumed in a general way that mineral veins were original cracks in the rocks containing matter that had been changed into vein minerals by some exhalations from the interior. Henkel supposed further that certain kinds of rock or stone which served as matrices were favorable and even absolutely necessary to the formation of vein minerals. Zimmermann, who, like Henkel, was a chemist rather than a miner,

considered that the material of veins, originally the same as the inclosing rock, had been altered by some saline solution and thus prepared for its final transformation into metallic minerals. The above, which might be called conversion theories, do not necessarily assume that veins are mechanically formed cracks, and hence of more recent formation than the inclosing rocks.

Von Trebra, a director of mines who was seeking for facts to aid in their exploitation, thought the changes observed in mountains took place slowly under the influence of heat and humidity, and expressed his idea of conversion as applied to veins more distinctly as the taking away of one constituent of a rock and replacing it by another. The agent of the transformation he called putrefaction or fermentation, by which names he wished to designate some unknown force which produced the chemical changes observed in the rocks.

Lehmann, a mineralogist and also a director of mines, supposed that the veins found in mines are only the branches and twigs of an immense trunk that extends to a great depth in the bowels of the earth, where nautre is carrying on the manufacture of the metals, and whence they travel toward the surface through rents in the rocks in the form of vapors and exhalations, as the sap rises and circulates through plants and trees. This general view is popular among practical miners even at the present day, probably because it appeals almost exclusively to the imagination.

Delius, Gerhard, and Lasius had the general idea that veins were fissures formed later than the inclosing rocks, which had been filled by materials brought in by circulating waters. The last went so far as to suppose that these waters contained carbonic acid and other solvents which enabled them to gather up metallic materials in their passage through the rocks. In this respect he approached closely to modern views, but he was in doubt whether the metals were contained in the rocks as such, or whether the solvents possessed the power of turning the substances they encountered in one place into lead and in another into silver or some other metal.

Of more permanent value were the works of Von Oppel (1749) and de Charpentier (1778), who were successively directors of the Saxon mines previous to Werner.

Von Oppel was the first to distinguish bedded deposits (lagergänge), or those which lie parallel with the stratification, from true veins. He also gave to the small branches from a main vein the name of "stringers" (trümmer), and noted that veins sometimes shift or fault the strata they cross, in which case he calls them "shifters" (wechsel). He laid stress on the importance of the causes which have produced rents or fissures in the earth, and shows how in the formation of mountains the rocks, being exposed to great desiccation and violent shocks, might split one from another, thus producing rents

with some open spaces, which being afterwards filled, would form mineral veins. "Where a vein has been cut or deranged by a visible rent," he remarks, "it is again to be met with by following the direction of this last."

Charpentier was a careful observer and a very cautious theorizer. He says, "Natural history will always gain more from true and accurate descriptions of her phenomena than from many and yet too-early explanations offered for them"—a most excellent principle which he admirably carries out in his own work. He presents many arguments derived from his own extensive observations in mines against the prevalent theory that veins were once open cracks formed by contraction, and that they had been filled by material flowing in from the surrounding rocks and hardening in them. Some of his objections were:

That contraction could not have made the kind of fissures that the veins are found to fill.

Open or empty spaces could not have existed under the conditions present when they were formed; pressure would have closed them.

The fragments of country rock as found in veins could not thus be accounted for. If they had simply fallen into an open crack, they would have accumulated at its bottom.

The comparatively uniform arrangement of ore in the vein, the enrichment caused by the crossing of one vein by another, the transition from vein material to country rock, etc., could not be explained on the contraction theory.

Having given his reasons why he believes that veins are not the filling of wide open spaces in the rocks, he says his readers will naturally ask how he supposes them to have been formed, and although he is not anxious to present a theory, he says he can not see from his observation of the workings of nature any other method for the formation of veins or other ore deposits than by an actual transformation of the rock material. Nature's processes have created innumerable small cracks and fissures in the rocks, and when a great number of such cracks lie together and in a common direction they might give rise to a considerable vein deposit. Vapors bringing in mineral solutions might penetrate these small cracks, as the sap rises in capillary tubes in organic bodies. If thereby the intermediate rock mass became changed into vein material, a vein deposit might be created without the necessity of wide empty spaces for its reception.

Rather more than usual space has been given here to Charpentier's work because of the striking contrast of his mental attitude with that of his great successor, Werner, whose reputation so completely overshadowed him that he has received less notice from later writers than seems to be his due.

THE SCIENTIFIC PERIOD.

The first scientific period may be said to have been entered on near the close of the eighteenth century, when De Saussure (1779), Pallas (1777), and Werner (1791) almost simultaneously inaugurated by their works the era of positive geology. It was about the same time that chemistry was placed on a scientific basis by the researches of Lavoisier, Scheele, Priestley, Cavendish, and others. Up to this time even the name geology had hardly been recognized, natural history or mineralogy being the titles usually given to works that treated of it, and the few exact facts with regard to it which such men as Agricola, Steno, and others had determined were drowned in a sea of conjectures. On the Continent it was the mining schools that principally fostered mineralogic and geonostic studies, and these had been but recently founded, that at Freiberg, Saxony, in 1765; at Schemnitz, Hungary, in 1770; at St. Petersburg, in 1783; and at Paris, in 1790. Geological literature, especially in Germany, went hand in hand with that on mining and mineralogy.

Of the three men just named, the two first were eminently observers. Pallas, after being called to the mining school at St. Petersburg, had made a six years' geological expedition through the mountains of Russia and Siberia, and De Saussure for over thirty years was largely busied in studying geological phenomena in his native Alps, being the first to climb Mont Blanc and Monte Rosa. He also appears to have been the first working geologist to use the name geology for his science. While neither of these men contributed much to the advancement of geological theory, they added largely to the store of ascertained fact, which is its necessary basis, and their greatest service, perhaps, was in inaugurating geological studies of the great mountain systems of the world, which more than any other branch of geological inquiry have been instrumental in raising this science to its present stand.

The actual field of observation of Werner, on the other hand, was extremely restricted, scarcely extending beyond the confines of his native Saxony. He had, however, a genius for the analysis, classification, and coordination of observations, which enabled him to bring order out of the chaos of fact and fancy which then constituted the science. With an eminently didactic mind, he possessed, with much personal charm, such a power of impressing his ideas upon his pupils, that during the forty years that he occupied the chair of mining and mineralogy the Freiberg school was the center of geological studies in Europe. From it emerged so many distinguished geologists, as the fruit of his teachings, that, as Cuvier says, " from one end of the world to the other nature was interrogated in the name of Werner."

Contemporaneously with Werner an equally great service was being

rendered to geology at Edinburgh, in Scotland, by James Hutton, who, like so many of the eminent geologists of the world, had been educated as a physician. Hutton, like Werner, taught mainly through his lectures, neither of them finding time for much writing, so that the doctrines of either have become known to posterity mainly through the publications of their pupils.

Each of these great teachers aimed to discard theory and to build their respective systems on a basis of ascertained facts, but in the then existing condition of geological investigation certain fundamental conceptions had to be assumed from the interpretation given to as yet imperfectly studied phenomena. With minds like theirs, strong in the courage of their convictions, an interpretation once fairly reasoned out and accepted became an established fact, and thus it came about that through a difference in their premises their respective systems were diametrically opposed and gave rise to the great controversy between Neptunists and Plutonists, which for nearly fifty years divided the scientific world of Europe into two antagonistic schools. Werner assumed that the earth had once been surrounded by an ocean of water at least as deep as the mountains are high, and that from this ocean there were deposited by chemical precipitation the solid rocks which now form the dry land. He entirely ignored the internal heat of the globe in its influence on crystalline rocks, on ore deposits, and as a cause of the dislocations of stratified rocks. Hutton, on the other hand, while not ignoring the agency of water in the formation of the sedimentary rocks, ascribed to subterranean heat and the expanding power it exercised their final consolidation, their disturbed condition, and the changes produced in the older rocks, to which Lyell later gave the name of metamorphism.

Neither made any distinction between dikes and mineral veins, but while Hutton supposed fissures and openings to have been formed from time to time which reached through the external crust down to the hot nucleus, and that both were formed by molten matter forced up through them toward the surface, Werner, on the other hand, taught that they were contraction fissures which were filled by material held in suspension or in solution; that a primeval ocean once covered them, and hence they must have been filled from above.

In general matters Hutton's reasoning and observations were both broader and more logical than Werner's, and his views have hence proved more enduring, but he had little, if any, personal knowledge of ore deposits. Werner made their study an important feature of the geologist's training, and his principal publication was entitled "A New Theory of Vein Formation." Although this work was the only important one exclusively devoted to the subject, owing to the fatal defects in his geological premises, it contributed little to the permanent advancement of that branch of the science, and it may even

be questioned whether it did not retard it, since through the great weight of the author's name it remained a standard work in Germany long after many of his peculiar geological theories had been discarded. Its merit lay less in the novelty of the views advanced, most of which had already been put forth by one or another of his predecessors, than in the logical way in which they were presented.

The principal points with regard to the origin of ore deposits which may be considered as fairly well established by Werner's teachings are that they are the filling of fissures and cracks of later formation than the inclosing rocks, and consist of foreign material subsequently introduced, largely in aqueous solution. As to the fissures themselves, while a certain systematic arrangement had been noted in their directions, and the fact that, where by intersection, one had been shifted or faulted by another, inferences as to their relative age might be drawn, little definite conception was apparently had as to their origin beyond the general suggestion that they might be the result of subsidence or of contraction of the rock masses in which they occur.

Any important advance over these rather crude conceptions was hardly to be looked for until very decided progress had been made in the broad general theories of geology, and this progress was necessarily very slow. Although the period of reasoning from facts of nature to generalizations had commenced, the tendency to pure speculation was not yet extinct, and resulted in many remarkable theories, such as that put forth by Professor Oken, of Jena, who, in his text-book of Natural Philosophy (1809), assumed that the earth was a polyeder formed according to the laws of crystallography, and that veins or fissures resulted from the loss of the water of crystallization. For the genesis of ores, darkness, earthy water, and air are necessary; hence there can be no ore in the interior of the earth, since no air reaches it, etc. Or, again, that of Breislak, the Italian geologist (1811), who put forth a plutonic earth theory which supposed that while the rocks were still in a molten condition the metals had a tendency to separate under the influence of specific gravity and of certain chemical and physical affinities, and localized themselves in veins without entirely separating from their country rock. This is apparently the first enunciation of the modern theory of magmatic segregation. The metallic grains in placers he supposed to have been granulated like slag on coming in contact with water.

The peculiar views of Werner naturally held sway longer in Germany than elsewhere, yet it was his favorite pupils that were first led, in their widening fields of observation, to abandon his theory that basalt is of aqueous origin, though altered by the heat produced through the combustion of neighboring beds of coal.

Von Buch, for a long time the leading geologist of Germany, was

perhaps the first to whom doubts came as to the correctness of his master's teachings, while studying an eruption of Vesuvius in 1799, though he refrained from immediate publication of these doubts.

D'Aubuisson, the French geologist, after visiting, in 1804, the volcanic regions of Auvergne, also became convinced of its igneous origin and published a recantation of the views maintained in his essay of the previous year on the aqueous origin of the basalts of Saxony. Finally, von Humboldt (1810), perhaps the greatest of his pupils, in his extended observations in the Cordilleran system of the American continents, traced a direct connection between metallic deposits and the eruptive rocks.

Observation must have convinced many of Werner's pupils of the untenability of his peculiar views on the formation and filling of veins long before their final refutation was published by his successor, von Beust, in 1840, but reverence for his memory doubtless prevented a definite expression of their opinions in print.

Von Herder, in his work on the Meissner adit, published in 1838, classified the various theories on the origin of veins that had been held up to that time, as follows:

1. Theory of contemporaneous formation (with the inclosing rock).
2. Theory of (filling by) lateral secretion, or by material derived from the inclosing rocks.
3. Theory of (filling by) descension, or filling from above.
4. Theory of (filling by) ascension, or filling from below, the latter subdivided into:
   (*a*) By infiltration, or solutions from mineral (thermal) waters.
   (*b*) By sublimation, or by ascending steam.
   (c) By sublimation, or in gaseous condition.
   (*d*) By injection or in igneous fluid state.

He was thus apparently the first to apply the now time-honored terms "ascension," "descension," and "lateral secretion," though the idea was clearly expressed thirty years before by Cuvier's collaborator, Alexandre Brogniart, when, in an attempt to reconcile the Huttonian and Wernerian schools, he showed that no one theory could fit all kinds of veins.

The theories of contemporaneous formation and of descension had by this time become practically obsolete among the Germans, and had never had much standing among geologists of other nations. German geologists, who have been the most assiduous students of vein phenomena in the field, have always been inclined to assume that vein minerals have been deposited by precipitation from aqueous solution, differences of opinion having been mainly as to the provenance of the waters. Doubtless the influence of Werner had much to do with their mental attitude, but it is also to be remarked

that this method of formation best fits the ore deposits of their country.

In England, the home of Plutonism, on the other hand, no very decided views on theories of ore deposition were held. John Maccullough, in 1821–1823, after a discussion of the Wernerian-Huttonian views, wisely concludes that it is necessary to study nature's processes more closely before a satisfactory theory can be formulated. He enumerates the minerals occurring in ore deposits which may be formed by infiltration or solution and by sublimation, contending that many vein minerals can be produced in either way, and recommends further investigations along that line.

John Taylor, in his report on minelar veins to the British Association in 1833, makes a similar review and arrives at similarly indefinite conclusions.

Later, De la Beche, in his Geology of Cornwall (1839), says:

> The theories of the day divide themselves into, first, the contemporaneous formation of mineral veins with the rocks which inclose them; second, the filling of fissures formed in rocks by the sublimation of substances driven by heat from beneath upward; and, third, the filling of fissures in rocks by chemical deposits from substances in solution in the fissures, such deposits being greatly due to electro-chemical agency.

The contemporaneous theory, according to him, was still generally held among Cornish miners, but he himself is evidently more inclined to the theory of deposition by solutions ascending under the influence of internal heat, the water being furnished from the sea, which covered many of the Cornish lodes.

The electro-chemical theory, which had already been suggested in 1810 by Bergrath Schmidt, and for a time enjoyed a certain popularity among English geologists, was founded mainly on observations made on the mine waters of Cornwall by Robert Ware Fox. This theory assumed that vein minerals had been precipitated from solution under the influence of electrical currents. It would appear, however, that, owing to the imperfect knowledge of chemistry of that time, the believers in this theory assumed electric currents to be a necessity for the production of certain reactions when they only serve to facilitate them. Fox's observations on the action of mine waters on minerals were, moreover, rendered somewhat inconclusive by the fact that he did not distinguish between primary vein minerals and those that have been formed during their secondary alteration by surface waters.

Among French geologists Plutonist views were predominant from the first; even those who, under the influence of Werner's magnetic teaching, had for a time embraced his Neptunist theory soon recanted it when their field of observation had widened to include vol-

canic regions. The cosmic theory, generally known as the "nebular hypothesis," the one which has been most universally accepted by geologists as an explanation of the earth's beginnings, as finally received, was the work of a French mathematician, Laplace (1796). Hence, in seeking to account for the origin of ore deposits they were naturally inclined to look for igneous agencies. Thus, A. Burat, well known through his work "Applied Geology," 1843, took extreme Plutonic views and divided the copper, lead, and iron deposits of the Italian peninsula, which he had especially studied, into (1) dikes or eruptive masses, with gangue of amphibolite and livaite; and (2) irregular veins of contact between eruptive serpentine and sedimentary rocks. The Elba deposits of specular iron, which he regarded as striking instances of the first class, he considered to have exercised an elevatory as well as metamorphic action on the inclosing rocks at the time of their injection. Fournet, another prominent authority on the subject, maintained a theory of igneous injection for vein fillings as late as 1859.

As in Germany, it was the professors in the mining schools, especially those at Freiberg, who, in the early part of the century, led in forming scientific opinion as to ore deposition, so it was the School of Mines at Paris which later furnished the leaders in that branch of geological thought.

The French students of underground phenomena were at a certain disadvantage as compared with their German brethren, in that they were obliged to travel to foreign countries to study large mines, whereas the German schools were all situated in the midst of important mining districts. On the other hand, while the German displays great industry and acuteness of observation in his collection of facts, the Frenchman has a remarkable faculty of logically grouping them and of clearly and concisely stating the conclusions to be drawn therefrom. The French language, moreover, by its structure is much better adapted to a concise presentation of scientific concepts that may be readily understood by the reader than the German, which is likely to be involved and cumbersome in its mode of expression. Hence, toward the middle of the century the influence of the French geologists on genetic speculation became predominant, especially as it was based on synthetic experiment, a branch of geological investigation which for a time they practically monopolized.

The first of the French geologists who has left an enduring impress upon the theory of ore deposits was Elie de Beaumont, who for nearly fifty years occupied the chair of geology at the Paris School of Mines (1827–1874). In 1847 he published, as an abstract of his lectures, his well-known paper "Volcanic and metalliferous emanations," in which he does not claim to formulate a complete or final theory, but presents his views as explanations which seemed to him best to fit the facts of

nature as then known. His conclusions are, briefly: That the metallic minerals in veins of incrustation (since called crustification) find their ultimate source in eruptive rocks, from which they emanate at first in gaseous form. As they pass through long canals or fissures, at greater distances from the center of eruption, they must condense and thus form deposits analogous to those of springs at their point of exit. The metals in veins are found united less frequently with oxygen than with certain elements to which the name "mineralizers" has been given, and which are not only volatile themselves, but possess the property of rendering volatile many substances with which they combine. These are sulphur, selenium, arsenic, antimony, phosphorus, tellurium, chlorine, bromine, iodine, etc.

Mineral springs he divides into principal or hottest thermals, which are fed by gases emanating directly from eruptive masses which reach the surface in a fluid state, and, second, less heated springs, which often accompany the former. The latter are fed by meteoric waters, which descend until they come in contact with hot rocks and, when heated, ascend again, in which journey they may be charged with mineral substances.

Vein deposits may be formed by either class of thermals; the second class would form deposits not only in ordinary fissures, but also in those already charged by direct emanations. It is difficult to account for the gangue minerals as direct emanations, since they are not volatile except such as are combined with fluorine. Certain deposits without gangue in eruptive rocks and deposits in limestone in contact with eruptive rocks, associated with garnet, ilvaite, and similar minerals, may have been deposited by sublimation, but these are exceptional. For most veins he admits, in accord with Bischof, that the earthy minerals must have come from the decomposition of the country rocks. The greater proportion of true veins (veins of incrustation) he considers to have been formed by deposition from waters circulating in cracks in the earth's crust. In this, his theory resembles Werner's, but differs from it in assuming that the solutions were ascending rather than descending. Werner's argument in favor of descending waters, namely, that veins become poorer in depth, he considers not well founded, the facts of nature rather going to prove that the solutions became weaker as they approached the surface.

Stanniferous veins, which contain a great number of the rarer elements and are associated with acid rocks, are the type of the first class, while ordinary or plumbiferous veins, which are characterized by the important rôle of mineralizers and the absence of anhydrous silicates, are usually associated with basic rocks.

His reasoning is evidently based largely on his observations in Cornwall, and on an assumed difference in the origin of granite and of volcanic rocks in general. Granite, he assumes, owes its crystal-

linity less to the fact of having crystallized at great depths than to its content of water (2 to 3 per cent), which enabled it to remain in a pasty condition much below its fusion point, and thus allowed quartz to take the impress of other minerals. The minerals of the first group of veins form part of the outer crust (penumbra) of granite bodies, as granite once formed the outer crust of the earth.

The products of volcanic eruptions he divides into two classes: (1) the lava-like, which consist of silicates in a molten condition; (2) the sulphur-like, which emanate in a molecular condition. To the latter alone can the formation of vein minerals be attributed. The term "solfataric," which was employed by subsequent writers to describe the action of the sulphur-like emanations, has since been very generally used by writers on ore deposits in a sense which is not always strictly accurate.

Although de Beaumont's views are based on some premises no longer considered tenable, they mark an important advance in this line of research, in that they may be said to be the first fruits of organized field investigation, for the first geological surveys, those of Great Britain and of France, had been founded about ten years before, and the first geological map of France had recently (1841) been completed by the latter survey, of which he was the founder and director.

This was also an era of experimental investigation, as well as of observation in the field. Following the example of Sir James Hall, who had, as early as 1805, spent some years in experimenting on the transformation of rocks under the combined influence of heat and pressure, French geologists were actively employed in attempting, by synthetical experiment in the laboratory, to imitate the processes of nature in the formation of rocks and minerals, especially of vein minerals. Prominent among those engaged in this work were Berthier, Becquerel, Ebelmen, Durocher, Sénarmont, and Daubrée. At first with heat alone and later employing heat and water combined, always under pressure, they succeeded in reproducing artificially a great number of the minerals of rocks and veins. Sénarmont (1849–1851), by the aid of water at temperatures of 130° to 300° C., formed artificially 30 of the principal minerals found in ore deposits, including quartz. The results of these experiments did not, however, prove decisively the agents which nature has employed, since they demonstrated that the same mineral may be formed by several different methods. This was appreciated by Daubrée, who, commencing his synthetical experiments with the artificial production of cassiterite in 1844, carried on experimental investigations into the mechanics of rock fracturing, the flow of subterranean waters, and rock metamorphism in general to near the close of the century. He was particularly impressed by his studies of

the mineral processes that have gone on since Roman times in the masonry of old thermal establishments at Plombières, Bourbonne-les-Bains, and elsewhere, in which he thought to trace the actual processes of vein formation. His works, Experimental Geology, 1879, and Subterranean Waters, 1887, which contain the first philosophic discussion based on experiment of the physics of the rock fractures that constitute canals for the circulation of underground waters, are still classic works of reference for the students of ore deposits. Daubrée understood veins to be fractures formed by dislocations of the earth's crust under pressure strains and filled by deposits from aqueous solutions, generally heated by contact with igneous rocks, from which in certain cases they may have directly emanated. From his observations at Plombières he inferred that most minerals are soluble if given sufficient water and time, and that great heat and pressure are not absolutely necessary prerequisites. Some of the materials of veins, he admitted, may have been derived from the surrounding rocks.

The middle of the nineteenth century was characterized by the increasing use of laboratory experiments in chemistry and physics as aids in testing the current theories of vein formation, as is shown in the preceding sketch of progress of opinions among French geologists.

Similar progress was going on in other countries, especially in Germany, which was more particularly a country of mines and mining engineers, though among students of this subject there was less solidarity of opinion than with the French, and their investigations for a long time were rather on chemical than on physical lines.

A great impulse to increased accuracy in geological investigation was given by the classic work of G. Bischof, Physical and Chemical Geology, 1846–47, which discusses in a masterly way the processes involved in most of the known geological phenomena, largely on the basis of the author's own researches and experiments, and which may be said to have raised chemical geology to the rank of a distinct science. In the course of his investigations, Bischof, having found that the constituents of the gangue minerals of veins are found in the country rocks, thought it probable that the metals of the sulphide ores might also exist in these rocks in the form of silicates. Later, and independently, Forchhammer, the Danish chemist, in the course of his long continued investigations of the waters of the ocean, detected minute amounts of many of the metals of ore deposits both in sea water and in different varieties of rocks. It was long before the suggestions offered by these discoveries had any practical effect on ore-deposit investigations.

The leading authorities (on ore deposits) of that period were Von Beust, Breithaupt, H. Müller, and Von Cotta. The latter for over

thirty years occupied the chair of geology at Freiberg, during which time he had opportunities of visiting most of the important mines of Europe. His text-book on ore deposits (1853–1859), which up to the end of the third quarter of the century was the standard authority both in Europe and America (through Prime's translation, 1869), may be assumed to be a good exponent of the knowledge of the time. It gives a fair-minded statement of all the theories which had been given to account for the formation of vein minerals, showing, however, a leaning toward the infiltration or hydrothermal theory of vein filling, based on the fact that some of the most common constituents are found in existing thermal waters, and that thermal waters containing CO_2 or H_2S are found in the deeper workings of some mines. In general, however, his views, whether on classes of deposits or individual types, do not betray the firm conviction that would result from an exhaustive and systematic study. Moreover, the fact that his classification of deposits is based on the more or less accidental character of form, without any reference to genesis, would indicate that his genetic ideas were still in a tentative state.

In 1873 Prof. F. Sandberger, feeling that the current theories inadequately explained many of the phenomena of vein deposits, followed out the suggestions of Bischof by making an extended series of analyses of the country rocks of veins. Separating previous to analysis the constituent minerals of the rocks by means of solutions of varying densities, he succeeded in demonstrating to his own satisfaction that the characteristic minerals of different deposits are contained in the basic silicates of the adjoining rocks, and in 1880 propounded his theory of lateral secretion, according to which the mineral contents of veins are derived, not from some unknown depth, but from the immediate wall rock, being brought in by percolating waters which are not necessarily at a very high temperature. As against the thermal-spring theory, he argued that a very small proportion of known thermals contain any of the metallic minerals whatever, and none in the state of sulphides; further, that the deposits observed in their channels have been precipitated in immediate proximity to the surface and under physical and chemical conditions that differ essentially from those that must have prevailed at the depths at which veins were formed.

Sandberger's theory, though for a time it found many adherents, was bitterly contested, especially by Stelzner, Von Cotta's successor at Freiberg, and by Posepny, professor at the Mining School of Pribram, in Bohemia. They maintained that the facts in their respective districts disproved the lateral secretion theory in the restricted sense in which Sandberger employed it, and they demonstrated by a repetition of his analyses that, owing to imperfect methods, he had not

proved the metals he found to be necessarily original constituents of the rocks in which they were supposed to occur. Whatever opinion may be held as to the merits of Sandberger's theory, as such, it undoubtedly contributed to the advance of the study of ore deposits in stimulating what may be called "verification;" that is, the practical testing of theory in its application to concrete instances in nature.

In general it may be said of the period that was now closing that, though facts of observation and experiment had been accumulating, the advances in the study of ore deposits during that time were much less than those that had been made in other branches of geological science.

THE VERIFICATION PERIOD.

The third period, covering in a general way the last quarter of the past century, may be called the period of verification. So fertile had been the imagination of previous thinkers on this subject that at this time it was practically impossible to conceive a theory of origin for a given ore deposit that had not already been proposed or at least suggested. The investigations now to be carried on with more perfect methods, or in the light of recent advances in the science, would seem more properly verifications of old theories than the propounding of new ones.

Method and the microscope have been the two great agents of progress. The greatest improvement in method has resulted from government aid, under which it has been possible for organized bodies of scientific workers to make special examinations of entire mining districts, and thus determine all the facts bearing upon ore deposition in those districts with an exhaustiveness that was impracticable for the unaided individual observer. The newly created science of microscopical petrography, through the intimate knowledge it has afforded of the internal structure of rocks and ores, has admitted so accurate a determination of the processes by which they have been formed that much that was formerly mere conjecture has become established on basis of fact. America, which hitherto had occupied a very subordinate position, had come to the front, not only in the production of metallic ores, but in its correct understanding of the processes by which they were formed.

In order to properly appreciate the progress which has been made during this period, one must endeavor to realize the mental standpoint of the average student at the close of the preceding period.

To the miner and prospector, whose opinions carry weight because of their wide practical experience, a typical ore deposit was a vein which, once an open crack extending to an indefinite depth, had been filled by material introduced in one way or another from below, and the more nearly a deposit approached this typical form the greater

its value. Indeed, for a time some of the most valuable deposits in the West were entirely neglected by the prospector because they did not possess the physical characteristics of the "true fissure vein." This misconception arose from the fact that this, being the most clearly defined form of deposit, had been the only one mentioned in early speculations, and that hitherto the classification of text-books, based as they were on the almost accidental characteristic of form, relegated other types of deposit to a distinct and relatively subordinate class, disregarding the fact that this class includes many of the largest and most productive ore bodies, which may not only have the same origin, but often be associated in the same deposit with a typical fissure vein.

Von Groddeck (on the other hand), who represents the most advanced scientific opinions of his time (1879), divides ore deposits into two classes:

1. Those formed contemporaneously with the inclosing rock, whether (*a*) sedimentary or (*b*) éruptive.
2. Those of later formation classed under two heads:
    (*a*) Those filling preexisting open spaces.
    (*b*) Metamorphic deposits formed by alteration of rock in place.

His two main divisions corresponded to a certain extent with those made in 1854 by J. D. Whitney (Metallic Wealth of the United States), namely, stratified and unstratified. One difference is that metamorphic deposits were included by Whitney in the first division and by Von Groddeck in his second. Neither recognized their true importance, and the latter, while admitting that he included in this class those that Stelzner had called metasomatic deposits, said they could not be regarded as separate deposits, because they are only incidental phenomena of the filling of cavities.

As a means of obtaining a clear view of the whole field, Von Groddeck divided known deposits into types (54 in number), characterized in the main by their varying mineralogical and lithological associations. Of these, 16 belong to his first subdivision, 5 to the second, 26 to the third, and 7 in part to the third and fourth, a classification which he admitted must be considered but tentative, owing to defects in existing knowledge which could be remedied only when all mines could be studied on a monographic or exhaustive system.

In America, though apparently unknown to Von Groddeck, such monographic studies had already been made—that of the Comstock lode by King (Fortieth Parallel reports, 1870), of the Lake Superior copper deposits by Pumpelly (Michigan geological survey, 1873), and that of the lead deposits of the Mississippi Valley by Chamberlin (Wisconsin geological survey, 1873–1879). These were followed in the early eighties by reports on the Comstock lode by Becker, on Lead-

ville by Emmons, on Eureka by Curtis, and on the copper-bearing rocks of Lake Superior by Irving—monographic studies which constituted an important feature in the plan of work laid out for the newly established United States Geological Survey. It was the expectation of those who planned this work that when all the important mining districts of the United States had been thus exhaustively studied, a sufficient store of well-ascertained facts regarding ore deposits would have been accumulated to admit of the formulation of a new theory more firmly grounded on a basis of well-established fact than any that had yet been presented.

It may be said of the deposits studied in the first decade of the Survey work that, in the form in which they were found, they were all determined to have been deposited from aqueous solutions and to be of later origin than the inclosing rocks. The lead and zinc ores of the Mississippi Valley might have been included in Von Groddeck's contemporaneous class if, as assumed by Whitney and Chamberlin, these metals had been deposited with the limestones at the time of their formation; but while, as to this ultimate source there is some difference of opinion, all are agreed that the concentrations which produced the workable ore bodies were of later date; hence it seems more logical to consider them of later formation than the inclosing rocks.

In the case of the other deposits studied, which were found to occur either in or in the immediate vicinity of eruptive rocks, it was assumed that the percolating waters had derived their metallic contents from some of these eruptive rocks, which careful tests had shown to contain small amounts of the various materials of the deposits. This derivation had an advantage over that of indefinite depth appealed to by the ascensionist or hydrothermal school, inasmuch as it admitted some sort of experimental proof, indirect though it was, and because at the depth at which the rocks might be supposed to be essentially richer in metals than those found at the surface, cracks sufficiently open to admit a free flow of thermal waters were considered impossible under the conditions of pressure assumed to exist there. This view was called a lateral-secretion theory, though it differed essentially from that of Sandberger, in that the derivation of the vein minerals was not restricted to the immediate wall rocks (Nebengesteine) of the deposits. Indeed, in a later discussion it was characterized as another form of the ascension theory. The circulating waters which had brought in the vein materials were assumed, though not always explicitly, to be of meteoric origin—waters which originally descending from the surface had become heated either in contact with igenous rocks or by the internal heat of the earth, and gathering up mineral matter in their journey had redeposited it when conditions favored precipitation rather than solution. The natural channels

through which these waters would circulate most freely, and which hence were most favorable to ore deposition, were rock fractures produced by dynamic movements in the crust; faults or joints to which Daubrée had given the designation "lithoclases." In no case were these fractures found to be contraction fissures, which Werner and many subsequent writers assumed to be the typical vein fissure, disregarding the consideration that contraction fissures could not traverse two distinct bodies of rock. To the joint-like fissures that are confined to a single bed, Whitney had already given the name "gash" veins.

In the Comstock Lode report, Becker had discussed mathematically the mechanics of faulting as applied to vein fissures, and had shown that an important characteristic of faulting on a fissure in solid rock is the tendency of the movement to separate the rock into sheets by subordinate fissures parallel to the main one. From practical observation Emmons had similarly concluded that the faulting movement which produced vein fissures was often distributed on a number of parallel fissures, thus producing a sheeting of the country rock. Where these fissures were sufficiently close together, so that the intermediate sheets of country rock were very thin and had been partially replaced by vein material, a banding would result which might be mistaken for that of the typical vein of incrustation. Where they were farther apart and of approximately equal strength, the mineral filling, instead of being confined to a single fissure, might be distributed on several, thus rendering frequent crosscutting advisable in their exploitation.

The idea that later-formed ore deposits are necessarily the filling of considerable cavities or open spaces in the inclosing rocks has been considerably modified by the important rôle that the process of metasomatic replacement or substitution has been shown to have played in the formation of ore bodies. The idea of replacement had been suggested in the conversion theories of the early speculators and more distinctly expressed by Charpentier. By the geologists of the second period it was comparatively neglected, though in a few cases admitted as a subordinate factor, especially in the formation of deposits in limestone. Even in Posepny's frequently quoted studies of the lead and zinc deposits of Raibl in Carinthia (1873), he admits this mode of formation only for the oxidized ores, considering the sulphide ores to have been deposited in open cavities.

In America Pumpelly first applied this process to the copper deposits of the Lake Superior region (1871), of which he says: "In at least very many instances, if not in all, the deposition of the copper is the result of a process of displacement of preexisting minerals."

Leadville and Eureka were the first large mining districts in which it was proved that extensive ore deposits were entirely formed by

metasomatic replacement of the inclosing rock, which in these cases was limestone. Later observations showed that this form of deposit was not confined to limestones, and that in fissure vein deposits, even in acid rocks, metasomatic processes had often played an important part in replacing by ore portions of the country rock which, under the old views, might have been regarded as vein filling. The interest and importance of this view were speedily recognized, especially by American geologists and mining engineers, and while still novel, it was doubtless sometimes applied without sufficient proof as an explanation of the formation of certain vein deposits to the exclusion of that of the filling of cavities or interstitial spaces. With the general introduction of the microscope into the study of vein materials, however, a comparatively sure method was provided of distinguishing the results of the two processes. The process of verification has in this case resulted in the establishment of the importance and increasingly wide applicability of the metasomatic theory to the formation of ore deposits of all types.

In the latter part of the decade Irving and Van Hise's studies of the iron deposits of the Lake Superior region had demonstrated that they had been deposited from solution in descending or meteoric waters, whose downward course had been arrested by some impervious basement—sometimes a dike, sometimes a bed in a synclinal basin—and that during this time of stagnation their load of iron oxide had been laid down as a metasomatic replacement of the inclosing rock, a descensionist theory, but of essentially modern type.

In 1893 appeared the well-known paper, "The Genesis of Ore Deposits," by Posepny, for ten years professor of this branch of the science at the School of Mines in Přibram, Bohemia. Although Posepny's views were by no means universally accepted by geologists, especially in America, all agreed that his work constituted a most valuable contribution to the science by its clear definitions of the questions involved and their masterly scientific discussion. The great majority of ore deposits Posepny considered to be of later origin than the inclosing rocks, even those that are found in stratified rocks in apparent conformity with the bedding. Further, that they have been deposited by precipitation from waters of the deep circulation below the ground-water level. The ground water he conceived descends by capillarity through rock interstices over large areas, to rise again at a few points through open channels under the influence of heat. It derives its mineral matter from the barysphere, or deep region, where the rocks are richer in metallic minerals than near the surface, and subsequently deposits them in open spaces as it ascends. These spaces are either spaces of discission (rock fractures) or spaces of solution, the latter sometimes being formed by ascending thermal waters, even where no previous crack exists.

Fresh as he was from his controversy with Sandberger over the lateral-secretion theory, which he had disproved, at least in its application to the Příbram deposits, he was inclined to view with disfavor anything that flavored of lateral secretion; hence, while admitting that the presence of minute quantities of the metals in eruptive rocks leads to the surmise that they had brought the whole series of heavy metals up from the barysphere into the lithosphere or upper crust, he preferred to assume, in the cases which the American geologists had explained as derivation from eruptive rocks in the vicinity of the deposits, that the mineral contents had been brought up by thermal waters directly from the barysphere. Likewise, in the limestone deposits, which their studies show to have been formed by metasomatic replacement, he thought that they must have overlooked some evidence of crustification, and still held to the opinion that such extensive deposits must be mainly the filling of open spaces. Although not explicitly stated, it is evident that he regarded the water of his deep circulation as mainly of meteoric origin.

Of great practical value was the clear idea conveyed to the mind of his readers of the distinction between the oxidized or altered minerals and the original or sulphide minerals of an ore deposit, a distinction previously pointed out, though less emphatically, by Emmons [a] and others.

In the same year appeared the first of a series of important articles on the formation of ore deposits by the Norwegian geologist, J. H. L. Vogt, in which, as opposed to Posepny's views, so much more importance is given to igneous agencies that their different standpoints recall the antagonisms of the old Neptunist and Plutonic schools. The petrographic studies of Vogt and Brögger had disclosed in basic dikes a tendency of the heavier minerals to concentrate near the borders. Following out the suggestion offered by this observation, Vogt had proved by field study that certain titaniferous iron ores were actual segregations in the eruptive magma previous to its final consolidation. Based on petrographic studies made by Brögger and himself, and personal observations on ore deposits, principally in Norway, Vogt defined two methods of formation of ore deposits as the direct result of igneous action:

1. By magmatic segregation.
2. By eruptive after-action of pneumatolysis (a term first used by Bunsen to describe the combined action of gases and water).

In the first class (of admittedly infrequent occurrence) are titaniferous iron ores, chromite, and other metallic segregations in basic eruptive rocks. In the second class, commencing with tin and apatite veins, he included, as time went on, increasingly numerous types of

[a] Colorado Scientific Society, vol. II, pt. ii, 1886, p. 99.

deposits. This was in one sense a revival of de Beaumont's theories, but the modern standpoint differed in that the existence of a liquid molten interior of the earth had been disproved by terrestrial physicists. Vogt held that as no communication could be established between ore deposits and a heavy interior, they must have been derived from a crust, say. 10, 25, or 50 kilometers in thickness, and in great measure the result of eruptive processes within that crust.

Emmons (in 1893) acknowledged the importance of the magmatic concentrations of metals in eruptive rock, but thought that in most cases such accumulations must have been further concentrated in order to produce economically valuable ore deposits.

During the second decade the influence of Posepny's paper was felt in an increased adherence among outside geologists and mining engineers to the ascension theory. Vogt's views received less attention in this country, because for a long time no ore deposits were studied to which they were found to be applicable. The first case was that of the titaniferous magnetites of the Adirondacks studied by Kemp, who published his results in 1898.

The year 1900 was rendered important in the progress of theoretical views on ore deposition by the simultaneous appearance of Principles Controlling Deposition of Ores, by Van Hise; Secondary Enrichment, by Emmons and Weed, and Metasomatic Processes, by Lindgren, and by the discussions which they prompted.

Van Hise's article was a broad, philosophic treatment, based on experimental data, of the whole question of underground circulation as bearing on ore deposition. It would be impracticable to give here any complete abstract of his paper, which is probably familiar to most of you, and only a brief statement of such points as bear on the general processes heretofore alluded to will be attempted. His discussion is practically confined to ore bodies deposited from aqueous solutions, which, he considers, embrace the larger proportion of workable deposits, and he holds that the waters from which these deposits have been made are chiefly of meteoric origin. Their circulation is in part descending, in part lateral moving, and in part ascending, and during each of these movements they may take up or deposit metallic minerals according as conditions favor either action. This circulation takes place in openings in rocks, mostly produced by fracture, and hence is confined to the outer portion of the crust, which he has defined as a zone of fracture as distinguished from a deeper zone, that of flowage, where, under accumulated pressure, deformation produces no macroscopic openings. Its general tendency is to concentrate from the small openings into larger or trunk channels. The deposits from these waters are distinguished as concentrations (1) from ascending waters alone; (2) from descending waters alone, and (3) first from ascending and second from

descending waters. In prevailing composition the first class are sulphides, tellurides, etc.; the second oxides or oxide salts, while the third are chiefly the one or the other, according as they were formed above or below the ground-water level.

Emmons and Weed, coming to the subject from a different but somewhat narrower standpoint—that of a practical field study, extending over several years—explained the frequent occurrence of bonanzas, or exceptionally rich portions of deposits just below the oxidized zone or ground-water level, as the result of leaching by surface waters of the upper portions of these deposits and their redeposition as sulphides in contact with preexisting metallic sulphides (especially pyrite) in the zone below. Through similar processes of chemical reasoning and with a similar disregard of Posepny's assumption that the ground-water level forms an effective barrier separating the action of the surface or vadose waters from that of the deep circulation, all three arrived at the same general conclusion with regard to the continuance of rich ore in depth, a question which has occupied the attention of geologists and miners since the days of Werner. This conclusion was that in most ore deposits a deeper region exists beyond the influence of surface waters in which the ore is of comparatively low and uniform grade. Van Hise even went so far as to say that in depth all deposits would become low-grade pyritic ores, and that all veins would eventually wedge out.

De Launay, in his generalizations on Mexican deposits, had already recognized three zones: (1) an upper oxidized zone, (2) a middle zone of rich sulphides, and (3) a lower zone of low-grade sulphides. He assumed the enrichment of the middle zone had been by descending waters, but placed it above the ground-water or hydrostatic level, which in many veins had probably been displaced since their original formation.

In his article "On metasomatic processes in fissure veins," Lindgren placed this theory for the first time on a scientific basis of chemical and microscopical study, and by a classification of veins according to the predominant metasomatic mineral or process involved he made its application much clearer to the student and observer. In his closing remarks he suggested that of late sufficient attention had not been given to the French theory of emanations from eruptive magmas, and that in the case of metals with low critical temperature they may have first been carried up under pneumatolytic conditions and with the aid of mineralizers while still above the critical temperature, until they reached the zone of circulating atmospheric waters.

His paper "On contact deposits," 1901, following out this suggestion, served a useful genetic purpose by calling attention to and clearly defining a group of deposits for which a pneumatolytic origin would readily be admitted, but of which no important examples had

yet been studied in America. The term "contact deposits," which had hitherto been loosely applied to all deposits, without regard to origin, which happened to lie near the contact of any two bodies of rock, was restricted by his definition to those occurring near the contact of igneous intrusives with calcareous beds. They are characterized by irregularity of form, the association of iron oxide and sulphides of the metals with various lime silicates, generally called "contact" minerals because they are found to be the result of contact metamorphism. Typical developments of these contact minerals near Christiania in Norway, in the Banat in Servia, in Tyrol, Italy, and elsewhere had been the subject of repeated study and discussion among European geologists since the middle of the century, but the metallic deposits connected with them being generally of subordinate economic importance had, up to the time of Vogt, not been considered worthy of a distinct place in the classification of ore deposits.

The importance of pneumatolysis in forming ore deposits was emphasized by the discovery on this continent, soon after the publication of Lindgren's paper, of a number of economically important deposits, especially of copper, which would come within his definition of contact deposits.

From a more theoretical point of view the contemporaneous paper of Kemp, "The rôle of igneous rocks in the formation of veins," presented a more decided opposition to the view so emphatically voiced by Van Hise, that the majority of our ore deposits have been formed by precipitation from circulating waters of original meteoric origin. In this Kemp maintains that ground-water circulation is not sufficient to account for the majority of ore deposits, but that igneous rocks must have furnished not only their metallic contents, but a large, if not predominating, proportion of the waters which brought them into their present position.

The controversy which had thus arisen as to the relative importance in the formation of ore deposits of waters of meteoric or of igneous origin has more recently received a further impulse in the discussions provoked by the presentation of proposed genetic classifications of ore deposits by W. H. Weed and J. E. Spurr. These geologists took an even more advanced position than Vogt in regard to the direct influence of igneous agencies in the formation of ore deposits, adding siliceous segregations to his class of magmatic differentiation products and very greatly enlarging the scope of his pneumatolytic class. The influence of these new views is already seen in the current literature on ore deposits, especially in articles where the author, though not in possession of full data, still feels it incumbent upon him to present some tentative hypothesis of origin for the deposits which he is describing.

RESULTS ACHIEVED.

The wide divergence of views shown by these discussions to be held by recognized authorities on the subject might lead one to conclude that we are as far as ever from a universal agreement on accepted theories. A more deliberate consideration of the progress of investigation and verification during this last period, which has been but too briefly and imperfectly set forth in the preceding pages, will show, however, that the advance in this direction has been real and permanent as far as regards the later stages of ore formation, which are more susceptible of actual proof, and that the disagreement lies rather with the ultimate or more theoretical sources of derivation, which must always remain to some extent matters of opinion.

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ON MOUNTAINS AND MANKIND.[a]

By Douglas W. Freshfield.

We have all of us seen hills, or what we call hills, from the monstrous protuberances of the Andes and the Himalaya to such puny pimples as lie about the edges of the Cambridge fens. Next to a waterfall, the first natural object (according to my own experience) to impress itself on a child's mind is a hill, some spot from which he can enlarge his horizon. Hills, and still more mountains, attract the human imagination and curiosity. The child soon asks, "Tell me, how were mountains made?" a question easier to ask than to answer, which occupied the lifetime of the father of mountain science, De Saussure. But there are mountains and mountains. Of all natural objects the most impressive is a vast snowy peak rising as a white island above the waves of green hills—a fragment of the arctic world left behind to commemorate its past predominance—and bearing on its broad shoulders a garland of the alpine flora that has been destroyed on the lower ground by the rising tide of heat and drought that succeeded the last glacial epoch. Midsummer snows, whether seen from the slopes of the Jura or the plains of Lombardy, above the waves of the Euxine or through the glades of the tropical forests of Sikhim, stir men's imaginations and rouse their curiosity. Before, however, we turn to consider some of the physical aspects of mountains, I shall venture, speaking as I am here to a literary audience and in a university town, to dwell for a few minutes on their place in literature—in the mirror that reflects in turn the mind of the passing ages. For geography is concerned with the interaction between man and Nature in its widest sense. There has been recently a good deal of writing on this subject—I can not say of discussion, for of late years writers have generally taken the same view. That view is that the love of mountains is an invention of the nineteenth century, and that in previous ages they had been generally looked on either with indifference or positive

[a] The address delivered to Section E (Geography) at the Cambridge meeting of the British Association, 1904. Reprinted from author's revised copy.

dislike, rising in some instances to abhorrence. Extreme examples have been repeatedly quoted. We have all heard of the bishop who thought the devil was allowed to put in mountains after the fall of man; of the English scribe in the tenth century who invoked "the bitter blasts of glaciers and the Pennine host of demons" on the violators of the charters he was employed to draft. The examples on the other side have been comparatively neglected. It seems time they were insisted on.

The view I hold firmly, and which I wish to place before you to-day, is that this popular belief that the love of mountains is a taste, or, as some would say, a mania of advanced civilization, is erroneous. On the contrary, I allege it to be a healthy, primitive, and almost universal human instinct. I think I can indicate how and why the opposite belief has been fostered by eminent writers. They have taken too narrow a time limit for their investigation. They have compared the nineteenth century not with the preceding ages, but with the eighteenth. They have also taken too narrow a space limit. They have hardly cast their eyes beyond western Europe. Within their own limits I agree with them. The eighteenth century was, as we all know, an age of formality. It was the age of Palladian porticoes, of interminable avenues, of formal gardens, and formal style in art, in literature, and in dress. Mountains, which are essentially romantic and Gothic, were naturally distasteful to it. The artist says, "they will not compose," and they became obnoxious to a generation that adored composition, that thought more of the cleverness of the artist than of the aspects of nature he used as the material of his work. There is a great deal to be said for the century; it produced some admirable results. It was a contented and material century, little stirred by enthusiasms and aspirations and vague desires. It was a phase in human progress, but in many respects it was rather a reaction than a development from what had gone before. Sentiment and taste have their tides like the sea, or, we may here perhaps more appropriately say, their oscillations like the glaciers. The imagination of primitive man abhors a void; it peoples the regions it finds uninhabitable with aery sprites, with "Pan and father Sylvanus and the sister nymphs;" it worships on high places and reveres them as the abode of Deity. Christianity came and denounced the vague symbolism and personification of nature in which the pagan had recognized and worshipped the Unseen. It found the objects of its devotion not in the external world, but in the highest moral qualities of man. Delphi heard the cry, "Great Pan is dead!" But the voice was false. Pan is immortal. Every villager justifies etymology by remaining more or less of a pagan. Other than villagers have done the same. The monk driven out of the world by its wickedness fell in love with the wilderness in which he

sought refuge, and soon learned to give practical proof of his love of scenery by his choice of sites for his religious houses. But the literature of the eighteenth century was not written by monks or countrymen, or by men of world-wide curiosity and adventure like the Italians of the Renaissance or our Elizabethans. It was the product of a practical common-sense epoch which looked on all waste places, heaths like Hindhead, or hills like the Highlands, as blemishes in the scheme of the universe, not having yet recognized their final purpose as golf links or gymnasiums. Intellectual life was concentrated in cities and courts; it despised the country. Books were written by townsmen, dwellers in towns which had not grown into vast cities, and whose denizens therefore had not the longing to escape from their homes into purer air that we have to-day. They abused the Alps frankly. But all they saw of them was the comparatively dull carriage passes, and these they saw at the worst time of year. Hastening to Rome for Easter, they traversed the Maurienne while the ground was still brown with frost and patched untidily with half-melted snowdrifts. It is no wonder that Gray and Richardson, having left spring in the meadows and orchards of Chambéry, grumbled at the wintry aspect of Lanslebourg.

That at the end of the eighteenth century a literary lady of western Europe should have preferred a Paris gutter to the lake of Geneva is an amusing caricature of the spirit of the age that was passing away, but it is no proof that the love of mountains is a new mania and that all earlier ages and peoples looked on them with indifference or dislike. Wordsworth and Byron and Scott in this country, Rousseau and Goethe, De Saussure and his school abroad broke the ice, but it was the ice of a winter frost, not of a glacial period.

Consider for a moment the literature of the two people who have most influenced European thought—the Jews and the Greeks. I need hardly quote a book that before people quarreled over education was known to every child—the Bible. I would rather refer you to a delightful poem in rhyming German verse, written in the seventeenth century, by a Swiss author, Rebman, in which he relates all the great things that happened on mountains in Jewish history; how Solomon enjoyed his Sommerfrische on Lebanon; how Moses disappeared on a mountain top and Elias was looked for among the mountains; how kings and prophets found their help among the hills; how closely the hills of Palestine are connected with the story of the Gospels.

Consider, again, Greece, where I have just been wandering. Did the Greeks pay no regard to their mountains? They seized eagerly on any striking piece of hill scenery and connected it with a legend or a shrine. They took their highest mountain, broad-backed Olympus, for the home of the gods; their most conspicuous mountain,

Parnassus, for the home of poetry. They found in the cliffs of Delphi a dwelling for their greatest oracle and a center for their patriotism. One who has lately stood on the top of Parnassus and seen the first rays of the sun as it springs from the waves of the Ægean strike its snows, while Attica and Bœotia and Eubœa still lay in deep shadow under his feet, will appreciate the famous lines of Sophocles, which I will not quote, as I am uncertain how you may pronounce Greek in this university. You may remember, too, that Lucian makes Hermes take Charon, when he has a day out from hell, to the twin-crested summit and show him the panorama of land and sea, of rivers and famous cities. The Vale of Tempe, the deep gap between Olympus and Ossa, beautiful in its great red cliffs, fountains, and spreading plane trees, was part of a Roman's classical tour. The superb buttresses in which Taygetus breaks down on the valley of the Eurotas were used by the Spartans for other purposes besides the disposal of criminals and weakly babies. The middle regions—the lawns above the Langada Pass, "virginibus bacchata Lacænis Taygeta"—are frequented to this day as a summer resort by Spartan damsels. The very top, the great rock that from a height of 8,000 feet looks down through its woods of oaks and Aleppo pines on the twin bays of the southern sea, is a place of immemorial pilgrimages. It is now occupied by a chapel framed in a tiny court, so choked with snow at the beginning of June that I took the ridge of the chapel roof for a dilapidated stoneman. I have no time to-day to look for evidence in classical literature, to refer to the discriminating epithets applied in it to mountain scenes.

A third race destined apparently to play a great part in the world's history—the Japanese—are ancient mountain lovers. We are all aware that Fusiyama to the Japanese is (as Ararat to the Armenians) a national symbol; that its ascent is constantly made by bands of pilgrims; that it is depicted in every aspect. Those who have read the pleasant book of Mr. Weston, who, as English chaplain for some years at Kobi, had exceptional opportunities of travel in the interior, will remember how often he met with shrines and temples on the summits of the mountains, and how he found pilgrims who frequented them in the belief that they fell there more readily into spiritual trances. The Japanese minister when he attended Mr. Weston's lecture at the Alpine Club, told us that his countrymen never climbed mountains without a serious—that is to say, a religious—object.

India and China would add to my evidence had I knowledge and time enough to refer to their literature. I remember Tennyson pointing out to me, in a volume of translations from the Chinese, a poem, written about the date of our King Alfred, in praise of a picture of a mountain landscape. But I must return to the six-

teenth and seventeenth centuries in Europe; I may go earlier—even back to Dante. His allusions to mountain scenery are frequent; his Virgil had all the craft of an Alpine rock climber. Read Leonardo da Vinci's Notes, Conrad Gesner's Ascent of Pilatus; study the narratives of the Alpine precursors Mr. Coolidge has collected and annotated with admirable industry in the prodigious volume he has recently brought out.[a]

It is impossible for me here to multiply proofs of my argument, to quote even a selection from the passages that show an authentic enthusiasm for mountains that may be culled from writers of various nations prior to 1600 A. D. I must content myself with the following specimens which will probably be new to most of my hearers.

Benoît Marti was a professor of Greek and Hebrew at Bern, and a friend of the great Conrad Gesner (I call him great, for he combined the qualities of a man of science and a man of letters, was one of the fathers of botany as well as of mountaineering, and was, in his many sidedness, a typical figure of the Renaissance). Marti, in the year 1558 or 1559, wrote as follows of the view from his native city:

"These are the mountains which form our pleasure and delight" (the Latin is better—"deliciæ nostræ, nostrique amores") "when we gaze at them from the higher parts of our city and admire their mighty peaks and broken crags that threaten to fall at any moment. Here we watch the risings and settings of the sun and seek signs of the weather. In them we find food not only for our eyes and our minds but also for our bellies;" and he goes on to enumerate the dairy products of the Oberland and the happy life of its population. I quote again this good man: "Who, then, would not admire, love, willingly visit, explore, and climb places of this sort? I assuredly should call those who are not attracted by them mushrooms, stupid, dull fishes, and slow tortoises" ("fungos, stupidos insulsos pisces, lentosque chelones"). "In truth, I can not describe the sort of affection and natural love with which I am drawn to mountains, so that I am never happier than on the mountain crests, and there are no wanderings dearer to me than those on the mountains." "They are the theater of the Lord, displaying monuments of past ages, such as precipices, rocks, peaks, and chasms, and never-melting glaciers;" and so on through many eloquent paragraphs.

I will only add two sentences from the preface to Simler's Vallesiæ et Alpium Descriptio, first published in 1574, which seem to me a strong piece of evidence in favor of my view: "In the entire district,

[a] "Josias Seinler et les originès de l'Alpinisnia jusqu'en 1600," par W. A. B. Coolidge. Allier Frères. Grenoble.

and particularly in the very lofty ranges by which the Vallais is on all sides surrounded, wonders of nature offer themselves to our view and admiration. With my countrymen, many of them have through familiarity lost their attraction; but foreigners are overcome at the mere sight of the Alps, and regard as marvels what we through habit pay no attention to."

Mr. Coolidge, in his singularly interesting footnotes, goes on to show that the books that remain to us are not isolated instances of a feeling for mountains in the age of the Renaissance. The mountains themselves bear, or once bore, records even more impressive. Most of us have climbed to the picturesque old castle at Thun and seen beyond the rushing Aar the green heights of the outposts of the Alps, the Stockhorn, and the Niesen. Our friend Marti, who climbed the former peak about 1558, records that he found on the summit "tituli, rythmi, et proverbia saxis inscripta unà cum imaginibus et nominibus auctorum. Inter alia cujusdam docti et montium amœnitate capti observare licebat illud:

"Ὁ τῶν ὄρων ἔρως ἄριστος."

"The love of mountains is best." In those five words some Swiss professor anticipated the doctrine of Ruskin and the creed of Leslie Stephen, and of all men who have found mountains the best companions in the vicissitudes of life.

In the annals of art it would be easy to find additional proof of the attention paid by men to mountains three to four hundred years ago. The late Josiah Gilbert, in a charming but too little-known volume, Landscape in Art, has shown how many great painters depicted in their backgrounds their native hills. Titian is the most conspicuous example.

It will perhaps be answered that this love of mountains led to no practical result, bore no visible fruit, and therefore can have been but a sickly plant. Some of my hearers may feel inclined to point out that it was left to the latter half of the nineteenth century to found climbers' clubs. It would take too long to adduce all the practical reasons which delayed the appearance of these fine fruits of peace and an advanced civilization. I am content to remind you that the love of mountains and the desire to climb them are distinct tastes. They are often united, but their union is accidental, not essential. A passion for golf does not necessarily argue a love of levels. I would suggest that more outward and visible signs than is generally imagined of the familiar relations between men and mountains in early times may be found. The choicest spots in the Alpine region—Chamonix, Engelberg, Disentis, Einsiedlen, Pesio, the Grande Chartreuse—were seized on by recluses; the Alpine Baths were in full swing at quite

an early date. I will not count the Swiss Baden, of which a geographer, who was also a pope, Æneas Silvius (Pius II), records the attractions, for it is in the Jura, not the Alps; but Pfäfers, where wounded warriors went to be healed, was a scene of dissipation, and the waters of St. Moritz were vaunted as superseding wine. I may be excused, since I wrote this particular passage myself a good many years ago, for quoting a few sentences bearing on this point from Murray's Handbook to Switzerland. "In the sixteenth century fifty treatises dealing with twenty-one different resorts were published. St. Moritz, which had been brought into notice by Paracelsus (died 1541), was one of the most famous baths. In 1501 Matthew Schinner, the famous Prince Bishop of Sion, built 'a magnificent hotel' at Leukerbad, to which the wealthy were carried up in panniers on the back of mules. Brieg, Gurnigel, near Bern, the Baths of Masino, Tarasp, and Pfäfers were also popular in early times. Leonardo da Vinci mentions the Baths of Bormio, and Gesner went there."

It is not, however, with the emotional influences or the picturesque aspect of mountains that science concerns itself, but with their physical examination. If I have lingered too long on my preamble I can only plead as an excuse that a love of one's subject is no bad qualification for dealing with it, and that it has tempted me to endeavor to show you grounds for believing that a love of mountains is no modern affectation, but a feeling as old and as widespread as humanity.

Their scientific investigation has naturally been of comparatively modern date. There are a few passages about the effects of altitude, there are orographical descriptions more or less accurate in the authors of antiquity. But for attempts to explain the origin of mountains, to investigate and account for the details of their structure, we shall find little before the notes of Leonardo da Vinci, that marvelous man, who combined, perhaps, more than any one who has ever lived the artistic and the scientific mind. His ascent of Monte Boso about 1511, a mountain which may be found under this name on the Italian ordnance map on the spur separating Val Sesia and the Biellese, was the first ascent by a physical observer. Gesner, with all his mountain enthusiasm, found a scientific interest in the Alps mainly, if not solely, in their botany.

The phenomenon which first drew men of science to Switzerland was the Grindelwald glaciers—"miracles of nature" they called them. Why these glaciers in particular, you may ask, when there are so many in the Alps? The answer is obvious. Snow and ice on the "mountain tops that freeze" are no miracle. But when two great tongues of ice were found thrusting themselves down among meadows and corn and cottages, upsetting barns and covering fields, and even the marble quarries from which the citizens of Bern dug their man-

telpieces, there was obviously something outside the ordinary processes of nature, and therefore miraculous.

Swiss correspondents communicated with the Royal Society the latest news as to the proceedings of these unnatural ice monsters, while the wise men of Zürich and Bern wrote lectures on them. Glacier theories began. Early in the eighteenth century Hottinger, Cappeller, Scheuchzer, that worthy man who got members of our Royal Society to pay for his pictures of flying dragons, contributed their quota of crude speculation. But it was not till 1741 that Mont Blanc and its glaciers were brought into notoriety by our young countrymen, Pococke and Windham, and became an attraction to the mind and an object to the ambition of the student whose name was destined to be associated with them. Horace Benedict de Saussure, born of a scientific family, the nephew of Bonnet, the Genevese botanist and philosopher, who has become known to the world as a mountaineer and the climber of Mont Blanc, came twenty years later. In truth, he was far more of a mountain traveler and a scientific observer, a geological student, than a climber. When looking at his purple silk frock coat (carefully preserved in his country house on the shore of the Lake of Geneva) one realizes the difference between the man who climbed Mont Blanc in that garment and the modern gymnast, who thinks himself par excellence the mountaineer.

De Saussure did not confine himself to Savoy or to one group; he wandered far and wide over the Alpine region, and the four volumes of his voyages contain, besides the narratives of his sojourn on the Col du Géant and the ascent of Mount Blanc, a portion of the fruit of these wanderings.

The reader who would appreciate De Saussure's claim as the founder of the scientific exploration of mountains must, however, be referred to the List of Agenda on questions calling for investigation placed at the end of his last volume. They explain the comparative indifference shown by De Saussure to the problems connected with glacial movement and action. His attention was absorbed in the larger question of earth structure, of geology, to which the sections exposed by mountains offered, he thought, a key; he was bitten by the contemporary desire for "a theory of the earth," by the taste of the time for generalizations for which the facts were not always ready. At the same time, his own intellect was perhaps somewhat deficient in the intuitive faculty—the grasp of the possible or probable bearing of known facts by which the greatest discoverers suggest theories first and prove them afterwards.

The school of De Saussure at Geneva died out after having produced Bourrit, the tourist who gloried in being called the historian of the Alps, a man of pleasant self-conceit and warm enthusiasm, and De Luc, a mechanical inventor, who ended his life as reader to Queen

Charlotte at Windsor, where he flits across Miss Burney's pages as the friend of Herschel at Slough and the jest of tipsy royal dukes. Oddly enough, the first sound guess as to glacier movement was made by one Bordier, who had no scientific pretensions. I reprinted many years ago the singular passage in which he compared glacier ice to "cire amollie," soft wax, "flexible et ductile jusqu'à un certain point," and described it as flowing in the manner of liquids (*Alp. J.*, IX, 327). He added this remarkable suggestion, foreshadowing the investigations of Professor Richter and M. Forel: "It is very desirable that there should be at Chamonix some one capable of observing the glaciers for a series of years and comparing their advance and oscillations with meteorological records." To the school of Geneva succeeded the school of Neuchatel, Desor and Agassiz; the feat of De Saussure was rivaled on the Jungfrau and the Finsteraarhorn by the Meyers of Bern. They in turn were succeeded by the British school, Forbes and Tyndall, Reilly and Wills, in 1840–1860.

In 1857 the Alpine Club was founded in this country. In the half century since that date the nations of western Europe have emulated one another in forming similar bodies, one of the objects of which has been to collect and set in order information as to the mountains and to further their scientific as well as their geographical exploration.

What bowlders, or rather pebbles, can we add to the enormous moraine of modern Alpine literature—a moraine the lighter portions of which it is to be hoped, for the sake of posterity, that the torrent of time may speedily make away with?

For fifty years I have loved and at frequent intervals wandered and climbed in the Alps. I have had something of a grand passion for the Caucasus. I am on terms of visiting acquaintance with the Pyrenees and the Himalaya, the Apennines and the Algerian Atlas, the mountains of Greece, Syria, Corsica, and Norway. I will try to set in order some observations and comparisons suggested by these various experiences.

As one travels east from the Atlantic through the four great ranges of the Old World the peaks grow out not only in absolute height but also in abruptness of form and in elevation above the connecting ridges. The snow and ice region increases in a corresponding manner. The Pyrenees have few fine rock peaks except the Pic du Midi d'Ossau; its chief glacier summits, the Vignemale, Mont Perdu, the Maladetta, correspond to the Titlis or the Buet in the Alps. The peaks of the Alps are infinite in their variety and admirable in their clear-cut outlines and graceful curves. But the central group of the Caucasus, that which culminates in Dykhtau, Koshtantau, and Shkara, 17,000 feet summits (Koshtantau falls only 120 feet below this figure), has even more stately peaks than those that cluster round Zermatt.

Seek the far eastern end of the Himalaya, visit Sikhim, and you

will find the scale increased: Siniolchum, Jannu, and Kangchenjunga are all portentious giants. To put it at a low average figure, the cliffs of their final peaks are half as high again as those of Monte Rosa and the Matterhorn.

In all these chains you will find the same feature of watershed or partings lying not in but behind the geological axis, which is often the line of greatest peak elevation. This is the case in the Alps at the St. Gothard, in the Caucasus for some 40 miles west of the Dariel Pass, in the Himalaya, in Sikhim and Nepal, where the waters flowing from the Tibetan Plateau slowly eat their way back behind Kangchenjunga and the Nepalese snows. The passes at their sources are found consequently to be of the mildest character—hills "like Wiltshire Downs," is the description given by a military explorer. It needs no great stretch of geological imagination to believe in the cutting back of the southern streams of Sikhim or the Alps, as for instance at the Maloya; but I confess that I can not see how the gorges of Ossetia, clefts cut through the central axis of the Caucasus, can be ascribed mainly to the action of water.

I turn to the snow and ice region. Far more snow is deposited on the heights of the central Caucasus and the eastern Himalaya than on the Alps. It remains plastered on their precipices, forming hanging glaciers everywhere of the kind found on the northern, the Wengern Alp, face of the Jungfrau. Such a peak as the Weisshorn looks poor and bare compared with Tetnuld in the Caucasus or Siniolchum in the Himalaya. The plastered sheets of snow between their great bosses of ice are perpetually melting, their surfaces are grooved, so as to suggest fluted armor, by tiny avalanches and runnels.

In the Aletsch glacier the Alps have a champion with which the Caucasus can not compete; but apart from this single exception the Caucasian glaciers are superior to the Alpine in extent and picturesqueness. Their surfaces present the features familiar to us in the Alps— ice falls, moulins, and earth cones.

In Sikhim, on the contrary, the glaciers exhibit many novel features, due, no doubt, mainly to the great sun heat. In the lower portion their surface is apt to be covered with the débris that has fallen from the impending cliffs, so that little or no ice is visible from any distance. In the region below the névé there are very few crevasses, the ice heaves itself along in huge and rude undulations, high, gritty mounds, separated by hollows often occupied by yellow pools which are connected by streams running in little icy ravines, a region exceptionally tiresome, but in no way dangerous to the explorer. In steep places the alpine icefall is replaced by a feature I may best compare with a series of earth pillars, such as are found near Evolena, in Canton Valais, and elsewhere, and are figured in most text-books. The ice is shaped into a multitude of thin ridges and spires, resem-

bling somewhat the Nieves Penitentes of the Andes, though formed in a different material.

Great sun heat acting on surfaces unequally protected, combined in the latter case with the strain of sudden descent, is, no doubt, the cause of both phenomena. Generally the peculiarities of the great glaciers of Kangchenjunga may be attributed to a vertical sun, which renders the frozen material less liable to crack, less rigid, and more plastic.

A glacier, as a rule, involves a moraine. Now, moraines are largely formed from the material contributed by subaerial denudation, in plain words, by the action of heat and cold and moisture on the cliffs that border them. It is what falls on glacier, not that which it falls over, that mainly makes a moraine. The proof is that the moraines of a glacier which flows under no impending cliffs are puny compared with those of one that lies beneath great rockwalls.

Take, for example, the Norwegian glaciers of the Jostedals Brae and compare them with the Swiss. The former, falling from a great névé plain or snowfield, from which hardly a crag protrudes, are models of cleanliness. I may cite, as examples, the three fascinating glaciers of the Olden Valley. The Rosenlaui glacier in Switzerland owed the cleanliness which gave it a reputation fifty years ago, before its retirement from tourists' tracks, to a similar cause—a vast snow plateau, the Wetterkessel.

One peculiarity very noticeable both in the Himalaya and the Caucasus I have never found satisfactorily accounted for. I refer to the long, grassy trenches lying between the lateral moraine and the hillside, which often seem to the mountain explorer to have been made by Providence to form grass paths for his benefit. They may possibly be due to the action of torrents falling from the hillside, which, meeting the moraine and constantly sweeping along its base, undermine it and keep a passage open for themselves. There are remarkable specimens of this formation on both sides of the Bezingi glacier, in the Caucasus, and on the north side of the Zemu glacier, in Sikhim.

Water is one of the greatest features in mountain scenery. In Norway it is omnipresent. In this respect Scandinavia is a region apart; the streams of the more southern ranges are scanty compared with those of a region where the snowfall of two-thirds of the year is discharged in a few weeks. Greece stands at the opposite pole. By what seems a strange perversity of nature, its slender streams are apt to disappear underground, to reissue miles away in the great fountains that gave rise to so many legends. Arcadia is, for the most part, a dry upland, sadly wanting in the two elements of pastoral scenery, shady groves, and running brooks.

The Alps are distinguished by their subalpine lakes—

> Anne lacus tantos; te, Lari maxime, teque
> Fluctibus et fremitu assurgens, Benace, marino?

of Virgil. But perhaps even more interesting to the student are the lake basins that have been filled up, and thus suggest how similar lakes may have vanished at the base of other ranges.

I know no more striking walk to any one interested in the past doings of glaciers than that along the ridge of the mighty moraine of the old glacier of Val d'Aosta, which sweeps out, a hill 500 feet high, known as "La Serra," from the base of the Alps near Ivrea into the plain of Piedmont. Inclosed in its folds still lies the Lago di Viverone; but the Dora has long ago cut a gap in the rampart and drained the rest of the inclosed space, filling it up with the alluvial deposit of centuries.

It is, however, the tarns rather than the great lakes of the Alps which have been the chief subjects of scientific disputation. Their distribution is curious. They are found in great quantity in the Alps and Pyrenees, hardly at all in the Caucasus, and comparatively rarely in the part of the Himalaya I am acquainted with.

A large-scale map will show that where tarns are most thickly dotted over the uplands the peaks rise to no great height above the ridges that connect them. This would seem to indicate that there has been comparatively little subaerial denudation in these districts, and consequently less material has been brought down to fill the hollows. Again, it is in gneiss and granitic regions that we find tarns most abundant—that is, where the harder and more compact rocks make the work of streams in tapping the basins more lengthy. The rarity of tarns in the highlands behind Kangchenjunga calls, perhaps, for explanation. We came upon many basins, but, whether formed by moraines or true rock basins, they had for the most part been filled up by alluvial deposits.

In my opinion, the presence of tarns must be taken as an indication that the portion of the range where they are found has, until a comparatively recent date, been under snow or ice. The former theory, still held, was that the ice scooped out their basins from the solid rock. I believe that it simply kept scoured preexisting basins. The ice removed and the surrounding slopes left bare, streams on the one hand filled the basins with sediment, or, on the other, tapped them by cutting clefts in their rims. This theory meets, at any rate, all the facts I have observed, and I may point out that the actual process of the destruction of tarns by such action may be seen going on under our eyes in many places, notably in the glens of the Adamello group. Professor Garwood has lately employed his holidays in sounding many of the tarns of the St. Gotthard group, and his results, I understand, tend to corroborate the conclusions stated.

I desire here to reaffirm my conviction that snow and ice in the High Alps are conservative agents; that they arrest the natural processes of subaerial denudation; that the scouring work done by a glacier is insignificant compared with the hewing and hacking of frost and running water on slopes exposed to the open sky without a roof of névé and glacier.

The contrast between the work of these two agents was forced upon me many years ago while looking at the ground from which the Eiger Glacier had then recently retreated. The rocks, it is true, had had their angles rubbed off by the glacier, but through their midst, cut as by a knife, was the deep slit or gash made by the subglacial torrent. There is in the Alps a particular type of gorge, found at Rosenlaui, at the Lower Grindelwald Glacier, at the Kirchet above Meiringen, and also in the Caucasus, within the curves of old terminal moraines. It is obviously due to the action of the subglacial torrent, which cuts deeper and deeper while the ice above protects the sides of the cutting from the effects of the atmosphere.

One more note I have to make about glaciers. It has been stated that glaciers go on melting in winter. Water, no doubt, flows from under some of them, but that is not the same thing. The end of the Rosenlaui Glacier is dry in January; you can jump across the clear streams that flow from the Lower Grindelwald Glacier. That stream is not meltings, but the issue of a spring which rises under the glacier and does not freeze. There is another such stream on the way to the Great Scheideck, which remains free when frost has fettered all its neighbors.

I should like to draw your attention before we leave glaciers to the systematic efforts that are being made on the Continent to extend our knowledge of their peculiarities. The subject has a literature of its own, and two societies—one in France, one in other countries—have been constituted to promote and systematize further investigations, especially with regard to the secular and annual oscillations of the ice. These were initiated by the English Alpine Club in 1893, while I was its president. Subsequently, though the exertions of the late Marshall Hall, an enthusiast on the subject, an international commission of glaciers was founded, which has been presided over by Doctor Richter, M. Forel, and others; and more recently a French commission, under M. Rabot, has been created with the object of studying in detail the glaciers of the French Alps. A number of excellent reports have been published, embodying information from all parts of the globe. There has been, and is, I rgret to say, very great difficulty in obtaining any methodical reports from the British possessions oversea. The subject does not commend itself to the departmental mind. Let us hope for improvement. I signalize the need for it. Of course it is by no means always an easy matter to get the

required measurements of retreat or advance in the glacial snout, when the glacier is situated in a remote and only casually visited region. Still, with good will more might be done than has been. The periods of advance and retreat of glaciers appear to correspond to a certain extent throughout the globe. The middle of the last century was the culmination of the last great advance. The general estimate of their duration appears to be half a century. The ice is now retreating in the Alps, the Caucasus, and the Himalaya, and I believe in North America. We live in a retrogressive period. The minor oscillation of advance which a few years ago gave hopes to those who, like myself, had as children seen the glaciers of Grindelwald and Chamonix at their greatest, has not been carried on.

Attempts are being made to connect the oscillations of glaciers with periods of sun spots. They are, of course, connected with the rain or snow fall in past seasons. But the difficulty of working out the connection is obvious.

The advance of the ice will not begin until the snows falling in its upper basin have had time to descend as ice and become its snout. In each glacier this period will vary according to its length, bulk, and steepness, and the longer the glacier is the slower its lower extremity will be to respond. Deficiency in snowfall will take effect after the same period. It will be necessary, therefore, to ascertain (as has been done in a tragic manner on Mont Blanc by the recovery in the lowest portion of the Glacier des Bossons of the bodies of those lost in its highest snows) the time each glacier takes to travel, and to apply this interval to the date of the year with which the statistics of deposition of moisture are to be compared. If the glacier shows anything about weather and climate, it is past not contemporary weather it indicates.

Another point in which the Asiatic ranges, and particularly the Himalaya, differ from the Alps is in the frequency of snow avalanches, earth falls, and mud slides. These are caused by the greater deposition of snow and the more sudden and violent alternations of heat and cold, which lead to the splitting of the hanging ice and snows by the freezing of the water in their pores. I have noticed at a bivouac that the moment of greatest cold—about the rising of the morning star—is often hailed by the reports of a volley of avalanches.

The botanist may find much to do in working out a comparison of the flora of my four ranges. I am no botanist; I value flowers according, not to their rarity, but to their abundance, from the artist's, not the collector's, point of view. But it is impossible not to take interest in such matters as the variations of the gentian in different regions, the behavior of such a plant as the little edelweiss (once the tol.en of the Tyrolese lover, now the badge of every Alp trotter),

which frequents the Alps, despises the Caucasus, reappears in masses in the Himalaya, and then, leaping all the isles of the Tropics, turns up again under the snows of New Zealand. I may mention that it is a superstition that it grows only in dangerous places. I have often found it where cows can crop it; it covers acres in the Himalaya, and I believe it has been driven by cows off the Alpine pastures, as it is being driven by tourists out of the Alps altogether.

The Italian botanists, Monsieurs Levier and Sommier, have given a vivid account of what they call the makroflora of the Central Caucasus—those wild-flower beds, in which a man and a horse may literally be lost to sight, the product of sudden heat on a rich and sodden soil composed of the vegetable mold of ages. Has any competent hand celebrated the mikroflora of the highest ridges, those tiny, vivid forget-me-nots and gentians and ranunculuses that flourish on rock-island "Jardins" like that of Mont Blanc, among the eternal snows, and enamel the highest rocks of the Basodano and the Lombard Alps? A comprehensive work on a comparison of mountain flora and the distribution of Alpine plants throughout the ranges of the Old World would be welcome. We want another John Ball. Allied to botany is forestry, and the influence of trees on rainfall, and consequently on the face of the mountains, a matter of great importance, which in this country has hardly had the attention it deserves.

From these brief suggestions as to some of the physical features of mountains I would ask you to turn your attention to the points in which mankind come in contact with them, and first of all to History.

I fancy that the general impression that they have served as efficient barriers is hardly in accordance with facts, at any rate from the military point of view. Hannibal, Cæsar, Charles the Great, and Napoleon passed the Alps successfully. Hannibal, it is true, had some difficulty, but then he was handicapped with elephants. The Holy Roman Emperors constantly moved forwards and backwards. Burgundy, as the late Mr. Freeman was never weary of insisting, lay across the Alps. So till our own day did the dominions of the House of Savoy. North Italy has been in frequent connection with Germany; it is only in my own time that the Alps have become a frontier between France and Italy. But questions of this kind might lead us too far. Let me suggest that some competent hand should compose a history of the Alpine passes and their famous passages, more complete than the treatises that have appeared in Germany. Mr. Coolidge, to whom we owe so much, has, in his monumental collection and reprint of early Alpine writers just published, thrown great light on the extensive use of what I may call the by-passes of the Alps in early times. Will he not follow up his work by treating of the great passes? I may note that the result of the construction of carriage roads over some of them was to concentrate traffic; thus the Monte Moro and the

Gries were practically deserted for commercial purposes when Napoleon opened the Simplon. The roads over the Julier and Maloya ruined the Septimer. Another hint to those engaged in tracing ancient lines of communication. In primitive times, in the Caucasus to-day, the tendency of paths is to follow ridges not valleys. The motives are on the spot obvious—to avoid torrents, swamps, ravines, earth falls, and to get out of the thickets and above the timber line. The most striking example is the entrance to the great basin of Suanetia, which runs not up its river, the Ingur, but over a ridge of nearly 9,000 feet, closed for eight months in the year to animals.

From the military point of view, mountains are now receiving great attention in Central Europe. The French, the Italians, the Swiss, the Austrians have extensive Alpine maneuvers every summer, in which men, mules, and light artillery are conveyed or carried over rocks and snow. Officers are taught to use maps on the spot, the defects in the official surveys being thus brought to light. It is not likely, perhaps, except on the Indian frontier, that British troops will have to fight among high snowy ranges. But I feel sure that any intelligent officer who is allowed to attend such maneuvers might pick up valuable hints as to the best equipment for use in steep places. Probably the Japanese have already sent such an envoy and profited by his experience.

A word as to maps, in which I have taken great interest, may be allowed me. The ordnance maps of Europe have been made by soldiers, or under the supervision of soldiers. At home, when I was young, it was dangerous to hint at any defects in our ordnance sheets, for surveyors in this country are a somewhat sensitive class. Times have altered, and they are no longer averse from receiving hints, and even help from unofficial quarters. Since the great surveys of Europe were executed, knowledge has increased, so that every country has had to revise or to do over again its surveys. In three points that concern us there was great room for improvement—the delineation of the upper region as a whole, the definition of snow and glaciers in particular, and the selection of local names. In the two former the federal staff at Bern has provided us with an incomparable model. The number of local names known to each peasant is small, his pronunciation is often obscure, and each valley is apt to have its own set of names for the ridges and gaps that form its skyline. Set a stranger, speaking another tongue than the local patois, to question a herdsman, and the result is likely to be unsatisfactory. It has often proved so. The Zardezan is an odd transcription of the Gias del Cian of patois, the Gîte du Champ in French. The Grand Paradis is the last term an Aostan peasant would have used for the Granta Parei, the great screen of rock and ice of the highest mountain in Italy. The Pointe de Rosablanche

was the Roesa Bianca, or white glacier. Monte Rosa herself though the poet sees a reference to the rose of dawn, and the German professor detects "the Keltic ros, a promontory," is a simple translation of the Gletscher Mons of Simler, or rather Simler's hybrid term is a translation of Monte della Roesa. Roesa, or Ruize, is the Val d'Aostan word for glacier, and may be found in De Saussure's Voyages.

I would urge mountain explorers to attempt in more distant lands what the late Messrs. Adams-Reilly and Nichols, Mr. Tuckett, and Lieutenant Payer (of Arctic fame) did forty years ago with so much success in the Alps, what the members of the Swiss Alpine Club have done lately, take a district, and, working from the trigonometrically fixed points of a survey, where one exists, fill it in by plane tabling with the help of the instruments for photographic and telephotographic surveying, in the use of which Mr. Reeves, the map curator to the Royal Geographical Society, is happy to give instruction. An excellent piece of work of this kind has been done by Mr. Stein in Central Asia.

There are, I know, some old-fashioned persons in this country who dispute the use of photography in mountain work. It can only be because they have never given it a full and fair trial with proper instruments.

Lastly, I come to a matter on which we may hope before long to have the advantage of medical opinion, based for the first time on a large number of cases. I refer to the effects of high altitudes on the human frame and the extent of the normal diminution in force as men ascend. The advance to Lhasa ought to do much to throw light on this interesting subject. I trust the Indian Government has taken care that the subject shall be carefully investigated by experts. The experience of most mountaineers (including my own) in the last few years has tended to modify our previous belief that bodily weakness increases more or less regularly with increasing altitude. Mr. White, the British resident in Sikhim, and my party both found on the borders of Tibet that the feelings of fatigue and discomfort that manifested themselves at about 14,000 to 16,000 feet tended to diminish as we climbed to 20,000 or 21,000 feet. I shall always regret that when I was traveling in 1899 on the shoulders of Kangchenjunga the exceptional snowfall altogether prevented me from testing the point at which any of our ascents were stopped by the discomforts due to the atmosphere. Owing to the nature of the footing, soft snow lying on hard, it was more difficult to walk uphill than on a shingly beach; and it was impossible for us to discriminate between the causes of exhaustion.

Here I must bring this, I fear, desultory address to an end. I

might easily have made it more purely geographical, if it is geography to furnish a mass of statistics that are better and more intelligibly given by a map. I might have dwelt on my own explorations in greater detail, or have summarized those of my friends of the Alpine Club. But I have done all this elsewhere in books or reviews, and I am unwilling to inflict it for a second time on any of my hearers who may have done me the honor to read what I have written. Looking back, I find I have been able to communicate very little of value, yet I trust I may have suggested to some of my audience what opportunities mountains offer for scientific observations to mountaineers better qualified in science than the present speaker, and how far we scouts or pioneers are from having exhausted even our Alpine playground as a field for intelligent and systematic research.

And even if the value to others of his travels may be doubtful, the Alpine explorer is sure of his reward. What has been said of books is true also of mountains—they are the best of friends. Poets and geologists may proclaim—

> The hills are shadows, and they flow
> From form to form, and nothing stands!

But for us creatures of a day the great mountains stand fast, Jungfrau and Mont Blanc do not change. Through all the vicissitudes of life we find them sure and sympathetic companions. Let me conclude with two lines which I copied from a tomb in Santa Croce at Florence:

> Huc properate, viri, salebrosum scandite montem,
> Pulchra laboris erunt præmia, palma, quies.

MOROCCO.[a]

By Theobald Fischer.

To the man of general culture the word "Morocco" calls up a vague notion of a country in the northwest corner of Africa, and even among the better informed a clear idea does not prevail that under the name "Morocco" is comprehended a group of countries and districts quite loosely tied together only by religious bonds, and that only a few of these constitute a sort of political union, the boundaries of which are ever changing, and which owes its existence to the dominant natural feature of the country, the Atlas range. The government and the people, perhaps for different reasons, have been alike at all times in maintaining the most distant attitude toward Europeans.

It has been only within the last twenty years that we have succeeded in throwing light upon even the main features of this extreme portion of the Dark Continent. Political aims have played a large part in bringing about this result, and it is therefore not surprising that French investigators, who are almost without exception officers in active service or pensioned, have accomplished most. The work of the Vicomte de Foucauld and, it seems, that of the Marquis de Segonzac—for his book has not yet appeared—belong to the highest achievements in the field of research on African soil. Much that is valuable, notably chartographic material, collected by French officers, especially of the mission militaire, on their travels through the country is probably lying unused in the maps of the French ministry of war. Other names worthy of mention are those of the Englishmen, Hooker, Maw, Ball, Harris, and of the Germans, Von Fritsch and Rein. I myself have devoted special attention to Morocco for many years, and in 1888, 1899, and 1901, I traveled through the country for purposes of investigation.

No presentation at all satisfactory from a scientific standpoint is in existence. The best map is that of R. de Flotte Roquevaire, on a

[a] Translated, by permission, from Geographische Zeitschrift, Leipzig, February 12, 1903. Translation revised by author.

scale of 1:1,000,000, for which he had a reliable basis to work upon in the map of P. Schnell, on a scale of 1:1,750,000, and also in the book by Schnell, which gives evidence of remarkable industry and insight.

On the southeast the boundaries of Morocco are quite indefinite; therefore its exact size can not be determined. On a rough estimate I ascribe to this group of countries a surface measure of 600,000 km². Of course I exclude Tuat and include Tafilalet, the whole district of the Draa, the province of Tekna, and all the country southward to the Sakiet-el-Hamra. For, as a matter of fact, the sultan at this day exerts a certain influence as far south as Cape Juby, since he bought the English trading colony there for a great deal of money, garrisoned it with about sixty men, and by means of yearly gifts prevailed on the real sovereign of the land, the Sheik El Maleynin, to place himself, to all external appearances, under the overlordship of the sultan.

So far as population is concerned, I will content myself with the statement that it amounts to about 8,000,000.

Thus Morocco is important, if only from its size and population; and its significance is increased by its situation and by its position relative to other countries, as well as by its extraordinary internal resources. Morocco is by far the most important of the three Atlas countries. Its situation enables it to maintain relations with the Mediterranean as well as with the ocean, and to share in the domination of the Strait of Gibraltar, the most important strait to the entire trading world. Its towns on the ocean, whose harbors could be made excellent without great cost, might be turned into stations for the world's commerce to West Africa, as well as to South and Central America, and even for the Mediterranean traffic. The relation of Larash to the Strait of Gibraltar is just as favorable as that of Cadiz. At the other extreme of Morocco, oases and springs make possible a communication with Nigeria through the great desert so active that until the most recent times, when the French tied up the routes, products of the Sudan were carried in great quantities to and through Morocco. Negroes formed a large percentage of its population, and Timbuctoo for a century acknowledged the authority of the Sultan. As late as 1887 the inhabitants of Timbuctoo declared to Naval Lieutenant Caron that they were a dependency of Morocco, though they said so, it is true, to ward off the French. The advantages of Morocco's climate, soil, and mineral products can not easily be overestimated. The provinces along the ocean coast, on account of their black soil, rank among the richest agricultural districts on the earth.

It is not yet possible to give a scientific exposition of the evolution of the main mountain ranges that divide the country latitudi-

nally and longitudinally, of the conditions which here created a group of lands bound together by a certain kind of union, loose as it is. At the same time, there is no doubt that here we have a piece of the great Eurasian mountain system. One group of its ranges—the Atlas Mountains of Morocco—extending to the southwest, ends abruptly at Cape Gir; the other—the Rif Mountains—continuing the Algerian Tell Atlas and bending to the north, also ends abruptly at the Mediterranean. The Rif Mountains are of a very recent origin, and, like the Tell Atlas of Algeria, essentially of the Eocene and Miocene periods. In fact, to judge from the Andalusian system, the folds continued to be thrown up as late as the Pliocene period, and presumably their composition is mainly Jurassic and Cretaceous, but toward the sea of older strata. The several parallel chains of the Rif Mountains, whose peaks are more than 2,000 m. high, present their precipitous sides to the Mediterranean, and with their narrow valley passes they thus form a secluded mountain region, difficult of access, which at all times enabled its Berber inhabitants to keep their necks clear of a foreign yoke. Marquis de Segonzac was the very first explorer who was able to cross it, and his work will soon give a better idea of it than is now possible.

The Rif coast, with its small coves, usually semicircular in shape, its small, rocky islands, and its secret nooks and crannies, by virtue of its proximity to the greatest strait in the world's commerce has, up to the present, been a coast for fostering the exploits of pirates, in defiance of the Spanish presidios. These strongholds, a remnant of better times to which the Spaniards still cling, lie in part on island rocks close to the coast (Peñon de Velez de la Gomera, Peñon de Alhucemas, Las Zafarinas), or on rocky promontories forming natural strongholds (Ceuta and Melilla). The natives keep the Spanish garrisons behind their walls and in their blockhouses in a constant state of siege, and the garrisons must obtain not only their food supplies from Spain, but even their drinking water.

Inland, toward the Atlas, the boundary of the Rif region is that of a valley, hydrographically well marked. Beginning with Thasa, of late so frequently mentioned, and strategetically a very important place, it extends to the west along the Innaun, an eastern tributary of the Sebu, the chief river of northern Morocco, and to the east along the Messun toward the Muluja, then along the winding Muluja itself, and finally along the Wed-el-Kseb, a western tributary to the Muluja, nearly to the border city of Udjda. This valley, forming a geologic demarcation and, as it were, a low pass, at a probable height of less than 1,000 m., constitutes the watershed between the Mediterranean and the Atlantic. From of old it has been a trading route of the utmost importance. It connects the Atlantic slopes of the Atlas lands, the Maghreb-el-Aksa, the extreme west of the natives, with the

Mediterranean regions; and it gives Morocco a firm hold upon the Muluja district, which constitutes a well-defined, distinctive territory for Morocco, and is a portion of the girdle of plain land beginning in Algeria at Oran. It has long been the endeavor of the French to connect the northern capital of Morocco, Fez, with Tlemsen, and thereby Morocco itself with Algeria, as with an iron clamp, by means of a railroad, which would traverse the route along the basin that I have described. To compare a large with a small thing, this basin is like the Arlberg pass, by which the Suabian Vorarlberg is connected with the Tyrol and Austria. West of Fez it broadens out toward the basin of the lower Sebu. Larash, at the northern extremity, or Rabat-Sla, at the southern extremity, of this basin, or Mehedyia, at the mouth of the Sebu itself, would thus be the Atlantic terminal of the great inland trading route, which is clearly defined by nature and which ends at the Mediterranean at Tunis. The basin of the Sebu in its general features resembles strongly that of the lower Guadelquiver. It is along the above-mentioned valley, now near Thasa, now near Fez, that the revolts are at present occurring, which seem to be carried on by the Berber tribes, Hiaina and Rhiata, living in the mountains on both sides of the depression.

Toward the west, and north of the basin of the Sebu, lies the district of Andjera, whose chief city is Tangiers, which by virtue of its position on the Strait of Gibraltar is the exit and entrance gate to Morocco from Europe. Andjera, the most northerly district, is filled by the Rif Mountains, which here turn their gently sloping side toward the ocean. This side of the mountains is composed of Tertiary strata, which form small plateaus separated from each other by swiftly flowing streams.

As yet we have little light upon the geologic history of the Moroccan Atlas Mountains and their relations to the Algerian Sahara Atlas. Of the Sahara Atlas it is known that its trend is southwest and northeast, that it was elevated mainly in the Eocene and Miocene periods, that it consists for the most part of three great groups of folds, the demarcation between the groups being orographically well defined. Some of its folds, which are less pronounced, take a more southerly direction, so that their mountainous character is, as a rule, not very distinct, especially since the enormous masses of detritus could not be carried off by running water after the dry period had been ushered in. The formation of the Sahara Atlas is chiefly limestone and sandstone, with here and there marl of the Jurassic and Cretaceous series; but Devonian and Carboniferous rocks appear among these, increasing toward the southwest, in the direction of the Moroccan Atlas, in the district of the Wed Gir and Susfana. The Moroccan Atlas range shows essentially different features from the Sahara Atlas, though the trend is in the same

direction. Older eruptive rocks; that is, porphyrite, diorite, and granite, which seem to be entirely lacking in the Sahara Atlas of Algeria, are here the most prominent, as is proved not only by the mountains themselves but also by the composition of the accumulations of detritus at the mouths of the valleys. This recalls the ancient denuded mountain ranges of the Iberian table-land. The crumplings in the Moroccan Atlas seem to have begun and ended sooner than in the other Atlas ranges; that is, at the end of the Cretaceous period.

According to J. Thomson, the same Cretaceous strata that lie flat and undisturbed in the Vorland are abruptly uplifted and form an essential feature of the Moroccan Atlas. Then these mountains would be older than the Rif Mountains, the Tell Atlas, and Sahara Atlas of Algeria. Paleozoic rocks are probably another large element in their structure. The process of upheaval was by far more intense, so that even to-day much higher ridges (3,000 to 4,000 m.) and peaks (4,000 to 5,000 m.) appear here than in the more recently formed ranges. The breadth of the range (about 200 km.), comprising a number of separate folds which constitute three parallel belts, the Great Atlas, the Anti-Atlas, and the Middle Atlas, is also much greater. The height of the ridges is everywhere considerable. Deep indentations do not occur in them. South of Marrakesh (the city of Morocco), lie three passes, the first 3,000 to 4,000 m. high, the second lying to the northeast of the first, 2,500 m., the third, to the southwest in the direction of the ocean, 1,000 to 2,000 m. The range thus forms a high wall, difficult to cross, about 1,000 km. long, separating the desert from the Vorland. Thus the Moroccan Atlas forms a mountainous region nearly as great in extent as the Alpine country between Nice and Vienna. Though in general, and not only on the side toward the Sahara, the whole range shows signs of comparative drought, which accords with its latitude and its situation in a dry zone. It receives so much snow during the winter that its peaks, covered with snow until late in the summer, which glisten down upon the dry, sun-scorched plain, and the streams in spring and early summer, fed by the melting snows, provide a quantity of water for irrigation.

The prevailing drought, increased by an almost complete destruction of the woods, the cold, and the covering of snow in winter, the rarity of wide valley plains, which, moreover, where they exist, are capable of culture only with the aid of artificial irrigation in summer—all these factors make the Moroccan Atlas less suited to habitation than one would expect. The population is limited to the chief valleys and thus only up to a slight elevation. Proper conditions are also lacking for cattle raising and mountain grazing. The region offers no allurements to the conqueror. Consequently, the Berber

Mountain folk, whose subjection was difficult, have always maintained their independence. It was scarcely possible for the masters of the Vorland countries to secure routes of communication for themselves with the other side of the mountains. They preferred to lock the passes by placing castles at their openings. It is a custom obtaining among the Berbers from the southern part of Tunis, south of Syrtis Minor, as far as the ocean, to stow their provisions and valuable possessions in castles, in Morocco called Tirremt, built upon safe heights by a village community or by a clan. This custom in some districts prevails to a striking extent. Moreover, the Berbers place their villages, as a rule, on precipitous heights. As a result the range, with its numerous strongholds and ruins of strongholds here and there, presents a remarkable aspect.

As J. Thomson has pointed out, the Great Atlas, strictly speaking, does not extend to the ocean, but only as far as the defile Asif Ig, some 50 kilometers from the coast. West of this point is table-land, including the provinces Mtuga and Haha. To the south, between the Great Atlas and the Anti-Atlas, lies a territory, broadening out to the ocean, called by the name of the Sus, the long Audinal river of the Atlas, by which it is watered. It is one of the most distinctive, by nature one of the most well-defined, districts in Morocco, and at the same time one of the richest in natural resources. Rich in mineral products, well watered, and fertile of soil, the land of Sus, which even at present has the largest share in the trade of Mogador, might, under a good administration, become a rich, cultivated district. The oasis city of Tarudant might become a focus of trade with the South, and Agadir, which has the best harbor on the ocean—closed now to foreign trade—might become a prosperous port.

The triangle made by the divergence of the Rif Mountains and the Moroccan Atlas forms the largest and most important province of Morocco. At all times this country, lying between the Atlas and the ocean, has been the heart of the group of lands constituting Morocco, the core of the body politic. I obtained an insight into its geologic history on my two last trips. The development of the present surface features is somewhat as follows: Probably toward the end of the Paleozoic period a precipitous mountain range was thrown up, formed mainly of Paleozoic schist, graywacke, quartzite, and argillaceous sandstone, interspersed with granite, porphyrite, and similar old eruptive rocks. Where the trend of the folds is still to be distinguished, it is approximately parallel with that of the Moroccan Atlas. The almost perpendicular strata of schist form here and there nearly horizontal plains, as though shaved off by a razor, but above these the more solid strata of graywacke, quartzite, and occasionally limestone, stand up in projecting ridges.

The Djebilet, a bare, rocky mountain range 100 km. long, which

limits the northern horizon of Marrakesh; the Dj. Achdar, the Dj. Karra, and similar small mountain ranges, present phenomena recalling those of the Taunus in Germany or the Sierra de Alcudiad, and other mountains of the Spanish table-land. The similarity between these primitive mountains of Spain and those of Morocco is in general very great, especially in so far as the older formations were overlaid by more recent deposits, consisting of strata entirely horizontal and still undisturbed, but merely elevated. The older formations show through the recent deposits only where rocks capable of more resistance jutted up, or where the recent formations yielded either to the energetic erosion and denudation produced by running water in the pluvial period, or to aerial denudation, which is almost the only force active since the pluvial period. It is to this force—aerial denudation—that the formation of table mountains is to be attributed. These occur frequently in the central belt of plain land and often stand together in groups. The thickness of the overlying deposits is not very great. So far as I could tell, it probably nowhere exceeds 100 meters. Concerning the chronology of its formation, sufficient paleontologic evidences are still lacking. On my last trip I brought fossils from Schedma—that is, from the extreme southwest—where disturbances connected with the upheaval of the Atlas are still important factors. E. Ficheur, who probably possesses the greatest knowledge of the geologic construction of Algeria, ascribed these fossils to the Cretaceous period. Going upon this assumption, I am of the opinion that the winding valley of the Tensift, which I followed in 1899 almost from its mouth to the sub-Atlantic high plateau at Marrakesh, was cut into this rock. According to A. Brives, state geologist in Algeria, and the first geologist to explore a portion of the Atlas Vorland, in the winter of 1901–2, the overlying mountains between the Tensift and the Um-er-Rbia, and north of this region, are to be ascribed for the most part to the Miocene period. The investigations of this geologist in Morocco are known only through a preliminary publication.

Accordingly, the Atlas Vorland for the most part has the character of stratified table-land. The dominating feature is that of plains—in fact, high plateaus. As far as our present knowledge goes, it may be assumed that two periods of uplift occurred, the one in Eocene and the other in Quaternary time. Consequently there are two levels—the coast plains and the high inland plateau—which comprise the greatest portion of the Vorland. The coast plain, whose geologic conditions I was able to distinguish clearly in my last trip (1901), begins at Cape Hadid, 20 kilometers north of Mogador, in a narrow point. At the foot of Dj. Achdar, which is the dominating landmark of central Morocco—that is, at Sidi Rehal—where the much-traveled caravan route from Mazagan to Marrakesh, in the valley of Mtal, climbs up to the higher level, the coast plain reaches its greatest

breadth of 80 kilometers. Northward, at the Um-er-Rbia, it narrows down to 70 kilometers; in Shawia, to 60 kilometers. Finally it disappears almost completely at Rabat, but in the valley of the lower Sebu it broadens out again to 70 kilometers, and here extends as far inland as the gorge of Sidi Kassem, in which the Rdem plunges down from the upper level. North of the Sebu valley the coast plain narrows down rapidly, but probably continues without break as far as the strait at Tangiers. At Arzila I found it still well defined, though with a breadth of only 10 kilometers, extending along the base of the Rif Mountains.

Thus the lower plain stretches along the ocean for a distance of 650 kilometers, but for the most part it rises straight up from the ocean, in the south to a height of 100 meters. Therefore the ocean coast of Morocco is to be regarded chiefly as one without prominent features, the rocky character of which is due to the close proximity of the older formations. The earthquakes that have repeatedly shaken the coast cities give ground for the supposition that there was a fault here. The coast line is therefore almost entirely unbroken, it being an exception when shelter for vessels is afforded by a shallow bay, such as at Mazagan, or by a small island produced by erosion, like Mogador, or where the breakers and the tides have cut out a bay from the valley of a small river or from a system of softer strata, as at Saffi and Casa Blanca. Real harbors are found only at the mouths of rivers, as at Azemur, situated at the mouth of the Um-er-Rbia; Rabat, at the mouth of the Bu Regreg; Mehediya, at the mouth of the Sebu, and Larash, at the mouth of the Lukkos. Unfortunately all these river mouths are practically closed by sand bars, due to the constant shifting of sands during nearly the entire year along the whole coast. As a rule only small vessels can cross the bars, and even these but rarely, when the sand is temporarily swept away by high tides. At these ports, as at all Moroccan ports, steamers must lie at anchor in the open roadstead and keep up their supply of steam, so as to be ready at a moment's notice to reach deep water. Besides, Azemur and Mehediya, situated at the mouths of the greatest rivers, both navigable for some distance, are closed to foreign trade, and are therefore of no significance whatsoever. In places, also, where more recent deposits have created a strip of plain and bays—that is, flat coast lands—as in front of the valley of the Sebu and in Dukkala, south of Mazagan, geographical conditions more favorable to trade have not arisen. Nevertheless it would seem as though the bay of Walidiya, north of Cape Kantin, a prominent landmark, might be turned into an excellent harbor.

An average height of 150 meters might be ascribed to the steep cliff with which the coast plain breaks off at the sea. Going inward from this edge the plain imperceptibly rises to a height of 250 meters

at the base of the higher plain, which in turn presents an abrupt elevation of 100 meters. Possibly the edge of the higher plain was once the shore of the ocean. The coast plain bears nearly everywhere the marks of a true plateau, and when one gets a bird's-eye view it appears to be level as a table. Here and there occur hills and undulations in the ground. Their infrequency is to be attributed to denudation and to the chalk crust so characteristic of expanses of land in Morocco and so fraught with danger, to be explained as essentially a climatic phenomenon. The primitive mountain crops out only in Shawia, where it forms isolated cliffs.

Apart from the large rivers rising in the interior, running water is utterly lacking in the coast plain. Most of the smaller streams and brooks that descend from the upper level soon dry out, but their valleys form an easy ascent to the higher table-land. The only strips of land intersected by running water are the precipitous coast land to a distance of 10 to 20 kilometers from the ocean and a narrow girdle on each side of the Um-er-Rbia.

As a consequence, springs are very rare in the lower plain, and they probably occur only in Shawai, where they are occasioned by the impervious folds of the primitive mountains now degraded, and in the belt along the Um-er-Rbia. For the most part in the countries immediately along the ocean the inhabitants are dependent upon artificial means of obtaining water, except where the great rivers from the Atlas provide good though usually muddy drinking water. The first expedient adopted by the natives was the construction of artificial ponds for collecting rain water, suggested by the natural pools formed on the chalk crust or in shallow basins. Such are to be found in great number throughout the district, notably in Dukkala, where there are many hundred, circular in shape, surrounded with low walls, and not seldom with a mound in the center. Some persons maintain that they are of volcanic origin, but they are undoubtedly products of human labor. I saw some that had just been made. Then, the people constructed cisterns on the edge of the chalk crust, which prevented the water from penetrating into the ground. Where these means failed to secure water for the eight or nine months of the dry season, wells are bored, but it is a very difficult task, as they must be dug to a great depth—I suppose as far as the impervious primitive mountain folds. Moreover, for the most part, stone for the construction of walls is lacking. I measured wells 60 meters deep. The water in them is warm and very often so saline that at first even animals did not want to drink it, and tea prepared with it is unpalatable. And yet sometimes a well of this kind is the only source for obtaining water in an entire district. In such cases they are always placed within the kasba (citadel) of the kadi, as a means of keeping the population in subjection. A draft

animal—a camel, horse, or mule—is employed all day long in pumping water to the surface through a large conduit. Not infrequently women are to be seen harnessed at the work. Here wind motors would be entirely suitable and they would never lack motive power.

The fact that these districts along the coast at present maintain a fixed population and are habitable to a high degree is the result of cultivation, of long, toilsome labor on the part of man. It is also the result of the remarkable fertility of the soil, which likewise accounts for the form of the plain. This lower plain land of the Atlas Vorland possesses a covering of black soil, or Tirs, as it is there called, which is spread over a large extent of territory. In 1899 I was in a position merely to indicate its existence, but in 1901 I could carry my investigations farther and verify my previous observations. I submitted specimens of the soil, obtained on both trips, to most competent specialists for chemical and mineralogical analysis; and those analyses not only declared the soil to be unusually fertile, but they also confirmed my theory as to its origin, which is that it consists essentially of dust deposits from the interior. The black soil is for the most part of slight depth and is spread unevenly; the broadest areas covered by it unbrokenly probably occur in Abda. Nevertheless, Dukkala is generally considered the most fertile of the coast provinces. I myself observed black soil in the upper plain lands of Shawia, but near the edge, and in the region of the upper Wed Rdem in El Gharb, and through inquiries I established the fact that of its presence in Tedla, the most inland valley of the Atlas Vorland, the Moroccan Ferghana, as I might call it.

This belt of black soil is therefore principally characteristic of the coast plain, where the dust carried down from the inland plains is retained because of a more abundant rainfall in winter, a more luxuriant vegetation, and the flatness of the land, which precludes washing away by swift-running streams. Consequently black soil is entirely lacking along the Um-er-Rbia and in the strips of land along the coast that are cut up by rivers. The remarkable capacity of this soil for water, which has been demonstrated by analysis, enables it to retain the winter moisture, and this moisture is supplemented to a certain degree by the abundant fall of dew peculiar to this coast region. Good results are thus obtained, both from a winter sowing and a spring sowing of maize or other grain. The peasants think that rain is even harmful to maize, for it seems to thrive on the natural moisture of the ground in winter and with the dew. About the first of April, when the winter rains are over, a variety is sowed that requires only three months for attaining its maturity, and may therefore be harvested at the end of June.

The lower plain land of the Atlas Vorland is thus the granary of Morocco, and the provinces included in it, Abda, Dukkala, Shawia,

and Gharb, are the richest and most densely populated of that country. Standing on the higher plain, the traveler views with astonishment the level stretches of Abda spread out at his feet as far as the eye can reach. He sees waving fields of wheat, barley, garden beans, chickpea, maize, canary seed, coriander, lentils, pease, and the like. Here and there are blue carpets of blooming flax, an innovation introduced by Europeans within recent years. The whole is strewn with white kubbas, glistening at a distance, and numerous little duars built of tabia; but not a tree, not a shrub. Forests are a product foreign to black soil. It is rare that even miserable looking fig trees or date palms are planted here and there.

By far the larger portion of the Atlas Vorland belongs to the upper tableland, which gradually rises from a height of 400 m. to a height of 600 to 700 mm. at the base of the Atlas Mountains that dominate the whole horizon. Here, too, the prevailing geographical feature is that of the plain, but not to the same extent as on the lower level. All the uplifts of the primitive degraded mountain forming small mountain ranges, like the Djebilet or the Dj. Achdar, the table mountains, tone down the monotony of the form. Moreover, the streams crossing the entire Atlas Vorland, especially the Tensift and the Um-er-Rbia, with their considerable fall and their strong current, frequently forming rapids, have cut deep, winding, often canyon-like valleys into the highland. These valleys are not only themselves impassable, being accessible as watering places only at certain points, but they also constitute serious obstacles in the way of travel. In the midst of magnificent savage scenery on a peninsula formed by a bend in the Um-er-Rbia, like the Marienburg on the Moselle, stands the mighty castle Bu-el-Awan, on the boundary of the two tablelands, the land of habitations and culture and the land of steppes. The castle has not, at the time of my visit, ever been reached by a European, which seems almost fabulous, though the natives assured me it is so.

The whole upper tableland, rather distant as it is from the ocean, receives only a slight rainfall, and has no black soil. The pervious soil of the younger strata, as well as the fundamental strata of the primitive mountains, which lack a coating of decomposed substances, occasion great dryness. Consequently the country consists of steppes, which, when the winters have been rainy or where the ground is richer and moister, are not wholly incapable of being cultivated for barley and, here and there, for wheat. According to important geographic features, such as the character of the soil, the presence of water sources, and the capability of cultivation, this district of steppes may be divided into two essentially different zones—the zone of real steppes and the zone of sub-Atlantic irrigated oases. The one, 80 to 100 km. broad, contains, it is true, some small oases, found chiefly in a belt along the Um-er-Rbia and owing their existence to springs; on

the whole, however, the zone consists of pasture land inhabited by nomads and seminomads. The number of herds of cattle, sheep, and camels is fairly considerable, especially because in summer, when the vegetation of the steppes, like a glorious carpet in late winter and spring, is scorched by the sun, the herds find nourishment either in the mountains or in the agricultural districts of the coast plain.

The most inland zone coincides with what I have called, from the character of the soil, the sub-Atlantic high plateau. This stretches along the base of the mountains for a distance of 330 km. and maintains a breadth of 30 to 40 km. All streams emerging from the mountains cross it. Mainly influenced, perhaps, by the ancient underlying strata, especially the Djebilet, these streams unite to form the two great drainage channels, the Tensift and the Um-er-Rbia. The watershed of the rivers is in the sub-Atlantic plateau itself, but as it is formed entirely of detritus, it is hardly distinguishable and probably underwent various essential dislodgments in the pluvial period. The detritus of the Atlas streams, probably accumulated for the most part in the pluvial period, though the process still continues, forms the predominant constituent of the soil in the sub-Atlantic zone. In this regard the zone recalls the valley plain lands of the Po, notably in Piedmont. All the Atlas streams afford enormous water supplies for purposes of irrigation, and are used for it even at the present time, although only a small fraction is accomplished of what might be done. The water supply is increased by underground sources, which are collected and brought to the surface by the so-called Chattaras, underground drainage canals, similar to the Kanat and the Kariz of Iran, the Sahrig of Yemen, and the Feggagir of some oases in the Sahara. Thus, the yellow steppe is dotted with dark oases along the streams and especially on the lower edge of the high plateau. In the largest oasis is the capital Marrakesh, a true oasis city, lying in a grove of date palms, the fruit of which ripens even at this elevation of 500 m. above sea level. It is the fruit trees that lend character to the oases and make this zone the least treeless of a treeless country. Besides the date palm there is the olive tree, the fig tree, the pomegranate, the orange, the lemon, the apricot, the peach, and the almond. Immediately under the fruit trees and in the vicinity of the groves, where the soil can be watered only in winter, grain, vegetables, and the like are cultivated. The zone to a large extent could be turned into an agricultural country, and water power for electric motors is abundant. Fortunately, the three zones of the Atlas Vorland might complement each other: The one produces breadstuffs in plenty, the other cattle, and the third fruit.

The mountain folk are dependent for their sustenance upon the Vorland, just as in Algeria the inhabitants of the desert are dependent upon the lands lying between the Tell-Atlas and the Mediterra-

nean. As a result, since permanent residence is offered by the nature of the country, small border cities, like Demnat, Sidi Rehal, Amsmis, and others have grown up at the mouths of the Atlas valleys.

The capital, Marrakesh, which gives its name to the country, is the chief city of the Tensift region. Although not situated directly on the Tensift, it has another advantage of being an oasis city in the open, high plateau. It developed in the first place as a result of its abundant water supply; in the second, through its position so favorable to trade. As in Milan, similarly situated at the base of the Alps, the Alpine routes converge like the spokes of a wheel, so the routes through the Atlas mountains and those to the Sus, and the region of the Wed Draa merge together at the city of Morocco, only to diverge again toward the coast towns Mogador, Saffi, Mazagan, Casa Blanca, and Rabat. Marrakesh, therefore, is the natural capital of all southern Morocco.

Fez plays the same rôle for northern Morocco and is the chief city of the Sebu region. Though only about 300 m. above sea level, it also lies on the upper plain. The highlands here, nearer to the mountain and lying between the Atlas and the Rif mountains, are partially cut up by hilly territory. Fez, as well as Marrakesh, owes its development to abundance of water, through which the city is adorned with a border of luxuriant gardens, and to the fact of its being a center of trade routes, whose direction is determined by natural conditions. It is the medium of trade between the mountains and the oases beyond, especially Tafilalet on the one side, the estuary of the Sebu, and the sea on the other. Indeed, thanks to the above-mentioned basin lying between the Atlas and the Rif mountains, it is the focus of trade of the entire Maghreb-el-Aksa with the other Atlas countries. It is proposed to build a railroad, over 100 kilometers long, to connect Fez with some point on the Mediterranean coast. From a strategic point of view it is the key at least to northern Morocco.

The entire Vorland falls into two divisions, according to the character of the soil, according to natural geographical routes, and, as a consequence of the latter, according to political conditions. The inhabitants of the two divisions regard them as entirely different realms, united only, as it were, in the person of the Sultan. The northern division, North Morocco, El Gharb, is predominatingly mountain and hill country, is well watered, and is almost everywhere capable of cultivation. South Morocco, El Haus, is for the most part high plateau, and lacks water, so that it can not be cultivated. By some Sus, the South, is regarded as a third division of equal rank with the other two. The border country between the sultanates of Fez and Marrakesh is one of the regions of which least is known, because the Berber tribes inhabiting it, who speak chiefly Tamazirt even at this day, and include the Zemmur, Zair, Zaian, Beni Mgild,

and Beni Mtir, keep all explorers aloof, without exception, and have prevented the armies of the Sultan and all conquerors from penetrating into their land or, at least, effecting a lodgment there. Even Roman domination extended only up to this border land. Though formed by the northern and northwestern projections of the Middle Atlas, which here thrusts itself forward toward the ocean like a wedge, this region, the basin of the Bu Regreg and the Wed Beht, a tributary of the Sebu, does not consist of high mountains. So far as I could ascertain, the country rises in natural terraces, with isolated peaks not much over 1,000 m. high, whose core is formed by the ancient underlying strata, which in great stretches has been laid bare by denudation of the overlying strata. It is the steep terraces, the rugged, rocky land, torn by ravines, thick with underbrush, and in the higher mountains partially covered by mighty cedars of the primitive forest, that have made it so difficult to penetrate into this region, while the inhabitants, whom the nature of the country made half nomad, are in a position, in case of need, to place themselves in security by withdrawing with their herds into the higher mountains, to which they betake themselves at any rate in the summer season.

On account of this impassable region all communication between North and South Morocco is forced into the one route along the ocean coast, and even the Sultan at the head of his army when he changes his seat from the southern capital, Marrakesh, to the northern capital, Fez, must take the same way. Rabat owes its strategic and commercial importance in greatest measure to this fact. Rabat is the connecting link between north and south, a great fortress in the sense of the term given it by the inhabitants of Morocco. Indeed, it is almost a bit of walled-in country, which, however, is kept nearly all the time in a latent state of siege by the tribes Zemmur and Zair. Thus an enemy common to North and South Morocco which besets Rabat separates the two districts from each other. As a result of reflection and counsel upon this point, the father of the present Sultan had a fort built through the agency of a former officer of the Prussian engineer corps, which, with its mighty Krupp guns, dominates the roadstead of Rabat.

Five German meteorological stations have been placed in Morocco; the two older, in Mogador and Saffi, were constructed by the German naval observatory, and I erected the two more recent stations, at Casa Blanca and Marrakesh. The fifth is at Maragon. The best of the meteorological stations is a sixth one at Lloyd's signal station on Cape Spartel. Climatic conditions, which have been investigated at these stations, may be said to be favorable, not only in the Atlas Vorland, but in the whole country. Malaria, the pest of the other Atlas countries, manifests itself here only slightly. Desert

country appears only beyond the Atlas range, and here cultivation is limited to some few oases and groups of oases, which, like the native land of the present dynasty, Tafilalet, are watered by the Atlas streams. On the coast land of this district, as far south as Cape Juby, the rainfall in winter is so abundant that there is a wide area of good pasture land, and barley can be planted in winters of copious rainfall even outside the river-watered oases. The average rainfall at Cape Juby may amount to 200 mm. As far south as Mogador, and probably some distance south of that city, the rainfall has attained 400 mm., which, to judge from observations in Tunis, is sufficient for agriculture; and to judge from my own observations, an additional advantage for agriculture is provided by the heavy dew that falls all along the coast and is to be attributed to the action of the trade winds, which, blowing off shore, carry out to sea the surface water and thus bring up the cool strata from the depths. At Casa Blanca the rainfall amounts to more than 400 mm., at Cape Spartel it reaches nearly 800 mm., at Tangiers it rises above 800 mm. Accordingly the entire coast land and all of North Morocco are capable of cultivation. In fact, in the Hinterland of Mogador, in the provinces of Shedma, Haha, and Mtuga wide areas are covered by open woods of evergreens, that is, of argan trees. The woods more frequently, it is true, mere coppices, extend 70 km. inland, where the steppes begin. I have already pointed out that also in the zone of steppes, where the rainfall probably remains considerably below 400 mm. at Marnakest (the average seems to be slightly more than 200 mm.) agriculture is not entirely out of the question. At the foot of the Atlas I saw wheat and barley fields on soil unwatered by rivers, which again gives evidence of increased rainfall.

The population of Morocco has not been the object of sufficient ethnologic investigation. My observations would lead me to the opinion that the Berber element is much more widely spread than is commonly supposed and that, even in the open country and the plains, it has been able to maintain itself as against the Arabic element although in many respects it is externally "Arabianized" and has adopted the Arabic speech. And yet on the high plateau a day's march east of Marrakesh I found Berbers that have preserved their own tongue. In the whole of North Morocco, even in the vicinity of Tangiers, live pure Berbers, the Amazirghs, and in the southwestern part of the Atlas Vorland, in Shedma, Haha, and Mtuga, and in the entire Moroccan Atlas, live the Berber Shilha. The Arabic element is predominatingly nomadic and limited for the most part to the plains of central Morocco; but the Arabic tribe of Howara, living among Berbers, has taken up settled habitation also in the Sus. As soon as you enter the hilly and mountainous districts you realize that

you are in the midst of a Berber population. The city population is mixed, but chiefly Berber, and the Berbers in Morocco cling to the soil, industriously devoting themselves to agriculture, truck farming, and tree growing. In the mountains they have introduced artificial irrigation and careful culture of the soil in terraces. Even the pure Berber tribes of the above-mentioned border land between El Gharb and El Haus have permanent villages in the mountains, in which they live, however, only in summer. The completely "Arabianized" Beni Ahsen in the low valley of the Sebu are also settled in their habits, even though they live in circular tent villages. Every night they drive their herds into the corral formed by the tents.

The number of negroes who originally came as slaves from the Sudan is very great in Morocco, and the farther south you go the more numerous they become. But this element is probably on the road to extinction, since increase by immigration is prevented by the French occupation of the Sudan.

Jews are scattered all over Morocco; individual families and groups are to be found far in the interior and in the villages of the Atlas. Like the Polish nobleman of former times, no kadi seems to be able to get along without his court Jew. They are most numerous in the cities, especially on the coast, where they enjoy most protection, and they are wandering there in numbers from the interior. They play an important rôle in trade and are also handicraftsmen to a large extent.

Morocco is entirely an agricultural and pastoral country. Mining is unknown to-day; an industry which once flourished in a high degree has fallen into utter decay. It scarcely produces the most indispensable articles of daily use, and gradually more and more dress material, metal ware, and the like are introduced from Europe. In consequence of the inconceivable misgovernment the greater part of the population is impoverished, the spirit of enterprise is deadened, the desire for gain weakened, the export of grain, cattle, horses, and other important objects forbidden, and the construction of roads and bridges unknown. Commerce, therefore, is but slight. Though the basis for the statement is not official, yet it is a fair estimate to place the value of the yearly exports and imports at about $13,750,000. The foreigners chiefly concerned in the exports are the Germans, who came to Morocco scarcely two decades ago, but in the imports the Germans yield place to the English and the French. By this time, however, German trade with Morocco is possibly second only to the English.

The government is so bad that in times of drought or locust plagues it can not ward off famine, despite all its restrictions upon export, and it provokes frequent uprisings, through which whole districts are systematically laid waste and their inhabitants killed off. In fact one

can say with safety at any time that there is a revolt going on somewhere in Morocco. In consequence of this misgovernment the population is nowhere dense, not even in the most richly blessed regions. I believe that the rate of density is not more than 50 heads per square kilometer in Abda, which is comparatively thickly settled, and in which one comes upon a duar, though usually a small one, every quarter of an hour. And I also believe that the estimate which ascribes a population of 8,000,000 probably comes pretty near the truth; but this is certainly the maximum. Only a portion of this population, however, is bound together by political ties and yields to the authority of the Sultan. Of the 600,000 square kilometers that I ascribe to Morocco by far the larger part belongs to what is in the country itself called Beled-es-Ssiba, "the independent territory," upon which the Sultan at best exercises influence as the religious head; and only 180,000 square kilometers are comprised in Beled-el-Makhzen, "the land of the chancery," which includes the provinces acknowledging the authority of the Sultan. The kernel of the Beled-el-Makhzen is the Atlas Vorland, of about 85,000 square kilometers and containing 3,000,000 inhabitants.

In the hands of a European power which could develop the resources of this country still lingering in mediævalism and could make its position count for all it is worth, Morocco might become a political factor of the first rank—might, indeed, be capable of bringing about a change in the distribution of power among the European States. At the same time, the fact must not be disregarded that it would be a long and difficult task to conquer the country. It would not be so hard to conquer the Atlas Vorland, which is open country throughout and easily accessible from the ocean, but all the more difficult to conquer the Atlas Mountain countries and the thickly populated Rif territory. But little help would be afforded by the existing division of the mountain folk into a number of small tribes, which rule themselves democratically and are in a state of constant feud and vendetta with each other, for their love of freedom is ungovernable and the nature of the ground presents very great obstacles. This is especially true of the natural route by which France could chain Morocco to herself, the valley mentioned in the early part of this article, along which at this very moment war operations are taking place, and which will not be safe until the mountain folk to the north and the south, the mighty tribes of Rhiata, Hiaina, and others, will have been completely conquered.

And it is these very North-Moroccan Berbers that are now armed with the best European breechloaders, which they obtained through the smuggling that goes on from Spain and Gibraltar and, perhaps, recently, from Algeria as well. It would seem as though the European powers, well aware of the frightful danger to the world's peace in-

volved in the discussion of the Moroccan question, wish even now at any cost to keep intact this State that holds European civilization in scorn. Perhaps the question for France is only to break the influence of the English, which has grown very strong at court. It is curious that, to judge from the expressions of the press, the German Empire would seem to have no political interests in Morocco, while the fact is that all trading countries are concerned in the question of the Strait, and, in so far as economic interests are involved, Germany holds the second place. These interests would be devoted to destruction, our position as a world power and a great commercial country would be endangered in the highest degree, were Morocco in any form whatever to fall into the hands of any one power, such as France, for instance. If sometime a change in the political map of this part of Africa becomes inevitable, the German Empire must get its share—El Haus and Sus. German interests at the Strait are protected, at need, if two powers hold each other in check there, Spain, it is self-understood, not being reckoned as a power. At all events, geographical conditions are favorable to a political division of Morocco, which in all times has been a dormant issue.

THE WORK OF THE RECLAMATION SERVICE.[a]

By F. H. Newell,

Chief Engineer of Reclamation Service, U. S. Geological Survey.

During the year 1904 there has been a notable increase in the knowledge of the possibilities of development of the West, and a long step has been taken toward the realization of some of these possibilities by the beginning of construction of large irrigation works by the Government. The funds for this purpose are furnished by proceeds from the disposal of public lands in thirteen States and three Territories, and the operations have been carried on by the reclamation service under the direction of the Secretary of the Interior.

The corps of engineers to which has been intrusted the work of planning and constructing the great irrigation works has been steadily increased and strengthened by the addition of experienced men through competitive civil-service examination. At the same time the energies of the corps as a whole have been directed toward examining into the possibilities of further work, reporting details of construction, and toward pushing forward the operations with as great speed and energy as are compatible with economy and thoroughness. The work has reached the stage where, in the spring of 1905, water will be put upon several thousand acres of land in Nevada, and many of the larger structures of national importance will be well underway.

In order to make choice of particular projects, it has been necessary to pass in review the physical conditions of the entire West and to consider from a broad standpoint the relative merits of an almost infinite number of possibilities. In any one State there are to be found feasible projects, large and small, and the entire reclamation fund and all of the energies of its engineers could profitably be devoted to that State. It is necessary, however, under the general terms of the law, to do something in each State or Territory and to expend as far as practicable the major portion of the fund derived from that State within its boundaries.

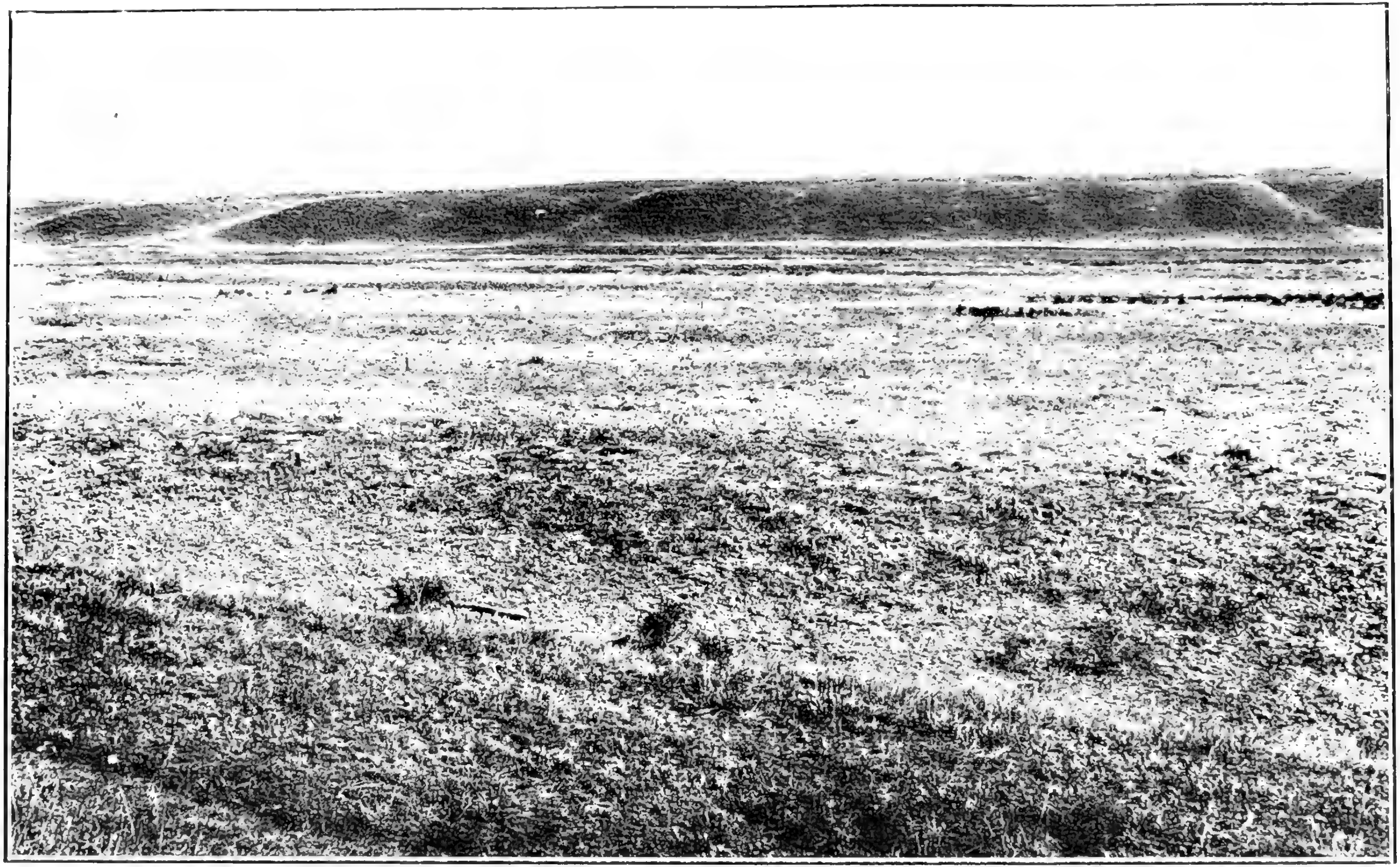
[a]An abstract of an address before the National Geographic Society, January 12, 1905, revised by the author and brought up to date. This article is in continuation of a paper printed in the Smithsonian Report for 1903, pp. 827 to 841.

For practical purposes the term "major portion" of the fund as used in the law is considered to be 51 per cent. That is to say, if in the course of time $2,000,000 is derived from the disposal of lands in North Dakota, at least $1,020,000 should be set aside for projects in that State, if found feasible, while $980,000 could be utilized elsewhere. If the entire fund from all the States and Territories amounted to $20,000,000, then $10,200,000 may be considered as fixed or restricted and $9,800,000 can be expended in one or more of the States according to the discretion of the Secretary of the Interior.

The problem of picking out the best projects is thus a double one. First, within each particular State and Territory the best scheme must be chosen, and second, taking all of the States and Territories, the best projects, irrespective of State lines, can then be selected and the minor portion of the fund utilized in their construction. There is thus offered a wide latitude for judgment and there is required for correct decision a full and comprehensive knowledge of the entire West. This knowledge is not confined to physical conditions or engineering details alone, but must take into account the social or political conditions and the financial problems involved—that is to say, the character of the people, the transportation possibilities, the kind of crops, and the markets for these, must all be taken into account, as well as the cost and permanence of the structures.

In order to give the Secretary of the Interior full information and advice concerning this great range of conditions, the reclamation service has been organized in such a way as to bring together men experienced in practical affairs and in engineering details. All matters of fact which bear upon the larger problems are assembled by men in the field, arranged and presented in concise form to boards of engineers convened from time to time to discuss the data and to arrive at definite conclusions. These engineers occupying consulting or administrative positions spend their entire time traveling about from point to point, personally examining all of the conditions, so that when brought together each man has a large fund of personal knowledge upon which to draw. This, and the new data presented, enables the board, with its past experience, to take up decisively a large range of facts and after discussion and deliberation present these in the form of a few definite recommendations.

For each project a board is convened consisting of the men who are most familiar with the essential facts. This board takes into consideration all matters of water supply, character of foundations, and materials for construction, also the design and operation of each part of the work; the character of the lands to be supplied, the amount of alkali in the soil, necessity of drainage, the climatic conditions, crops to be grown, transportation and market facilities, together



CANAL LINE CROSSING ON DUNLAP CREEK, MONTANA. FORT BUFORD PROJECT.

TYPICAL SCENE IN NORTH PLATTE CANYON, JUST ABOVE PATHFINDER DAM SITE, WYOMING. PATHFINDER PROJECT.

with numerous other details. After going over all of these matters on the ground the project board puts its recommendations in writing. These are transmitted to the chief engineer and by him to the Director of the Geological Survey, and finally to the Secretary of the Interior. These recommendations generally lead up to construction. Contracts are prepared after advertisements have been widely distributed and bids are received after the usual manner.

It must not be supposed that when the work of the reclamation service was begun by the Government there was an untouched field for its operations in the arid regions. On the contrary, private and corporate enterprise had been for years at work in the West and had considered nearly every opportunity which exists. In fact, one of the chief arguments for the passage of the reclamation act was that private enterprise had practically exhausted the field from the standpoint of financial returns, and if the West was to be developed and homes made for a great population it could only be done by the Government taking up the matter, not for direct profit in dollars and cents, but on a basis of getting back the investment without interest and without profit. The indirect gain to the whole country would be far larger than the loss of interest on the investment. In going over the ground, therefore, it has been found that the speculator has not been idle. He has filed upon or now claims nearly every natural opportunity in the way of water rights or of reservoir location. The laws of the United States are very broad, and practically any man can file upon or lay claim to lands available for purposes of power development or water storage. It thus becomes possible for the speculator to tie up and remove from use many of the great natural resources of the West. For example, a corporation developing electric power at one point can file upon and secure every other power site for hundreds of miles, and at relatively small expense create a monopoly. The Government coming into the field later is frequently put in the position of being compelled to buy back at large cost the valuable rights which it has recently given away.

The State laws regarding water rights are in many cases very indefinite and speculators can, by posting notice, lay claim to the waters of various rivers, although they do not have the financial means to utilize them, or they may make filings upon reservoir sites or enter under the various land laws tracts of land which command the situation. It thus results that reservoirs can not be constructed without buying out these rights at high prices. In short, the present land laws and their administration favor monopoly in water, and the Government or the bona fide investor is at great disadvantage in attempting to develop the country or to create homes for settlers. These conditions have greatly hampered the work of the reclamation service.

If it were possible to find any considerable number of localities

where the Government could go in with a free hand, take the unutilized waters, build the works without impediment, and divert the water to public land, the problem would be very simple. On the contrary, the reclamation service must first ascertain, often at great expense and after a long delay, the fact as to whether there is any water not yet appropriated, and whether it is possible to establish a legal claim to this water. It must then endeavor to get a clear title to the sites for its hydraulic works, as most of these commanding positions have already been seized by speculators. The owners of small tracts scattered here and there through public lands must be organized into water-users' associations in order that they may be dealt with on a business basis. The building of the works is relatively a simple matter compared to the solution of many of these problems, which require that the engineers shall be at the same time business men and that they may have the assistance of shrewd and able lawyers and financiers.

Among the most difficult matters to be determined is the relation between private enterprise and the operations of the reclamation service. It must be borne in mind at all times that practically all of the irrigation development of the West has been carried on by individuals or associations, and that while most of the easily constructed works have been built, there are others which are still attractive to the promoter. In nearly every locality where there are opportunities of reclaiming public lands on a large scale, it also happens that there is something which may be made a source of profit to a shrewd investor.

It may be said, generally speaking, that no large irrigation work has been financially successful. It has frequently been pointed out that all irrigation works may be divided into two classes, roughly designated as large and small. The small works or ditches built by farmers or associations of settlers have, almost without exception, been successful in every respect. The large enterprises, where stock and bonds have been sold and capital brought in from the East or from foreign countries, have, almost without exception, proved financially unprofitable and have had a long and involved history of disappointment and occasional bankruptcy. Nevertheless, in spite of this almost universal experience, there are still optimistic individuals who plan to avoid all failures of the past and prepare glowing prospectuses of new enterprises which it is alleged, if properly manipulated, will bring large returns to investors. As soon as the Government shows an interest in any particular locality some energetic promoter at once concludes that there may be something there which may be of value to himself. If it should be decided that a project must be stopped as soon as any private interest of this kind is encountered, the work of the reclamation service would soon come to a halt.

As before stated, nearly every possibility of reclamation has been under consideration by somebody at some time, and while every effort should be made to avoid interference, it is not fair to the communities concerned nor to the Commonwealth for the reclamation service to step aside in favor of speculative enterprises, especially when they would only partly develop the opportunities.

The following paragraphs are quoted from a statement by Hon. Thomas R. Bard, a Senator from California, and chairman of the Senate Committee on Irrigation:

It is recognized that the primary purpose of the reclamation act is to utilize the public domain by means of irrigation and make it available for occupation by settlers. The right to the use of the water provided by the expenditure of the reclamation fund must be permanently attached to the land irrigated, and "beneficial use" is made the basis, the measure, and the limit of the right. In every case where a considerable part of the irrigable lands are owned by the Government it is clearly inconsistent with the spirit of the act to permit such lands to be subject forever to a load of charges for interest and profits to be paid upon private capital invested in the irrigation works, these charges being in addition to a high cost of maintenance. This is especially questionable where the water, instead of being attached to the land as an appurtenant right, is owned and controlled by nonresident landlords.

The reclamation act applies also to land in private ownership, and it is plain that the general welfare of the nation requires that the water resources should be made to subserve the greatest possible good. The declaration of the law that the right to the use of the water shall be appurtenant to the land and that beneficial use shall limit the right must be undersood as a recognition of the general principles and policies.

By keeping the obvious intent of the law in mind it will be possible to solve many of the difficult questions which arise when private irrigation enterprises interfere with Government projects. It is clearly the duty of the Reclamation Service to investigate and determine whether a given private enterprise is competent to utilize the irrigation resources to the fullest extent, and whether the private works are of a permanent character. It is entirely proper for the Service to refuse to abandon its own projects until satisfactory guaranties are given that these requirements will be provided.

In short, the Service may, in the interest of the public, determine what shall be the character and scope of the work to be undertaken by private enterprise in this particular locality, and what shall be the burden to be carried by the irrigated lands, and may properly assert that a compliance with such requirements shall be the conditions upon which the Government shall surrender its right to provide the works and abandon its project.

The reservoir sites and similar essential portions of a comprehensive project should be withdrawn from speculative entry by the Reclamation Service and held for the largest practicable irrigation development. In cases where withdrawals have been made and investigations begun, and where promoters ask the Reclamation Service to step aside for their own benefit, they should be able to show, first, that they intend to construct in good faith and are not merely speculators, and, second, that the project to be constructed will be of real public benefit, will develop the country fully, and will not act as an obstruction to more comprehensive or economical systems.

The fund created by the act of June 17, 1902, is added to from time to time by the proceeds from the disposal of public lands. These proceeds for the fiscal year ending on the 30th of June are as follows:

1901	$3, 144, 821. 91
1902	4, 585, 520. 53
1903	8, 713, 996. 60
1904 (approximate)	6, 568, 497. 42
Total	23, 012, 836. 46

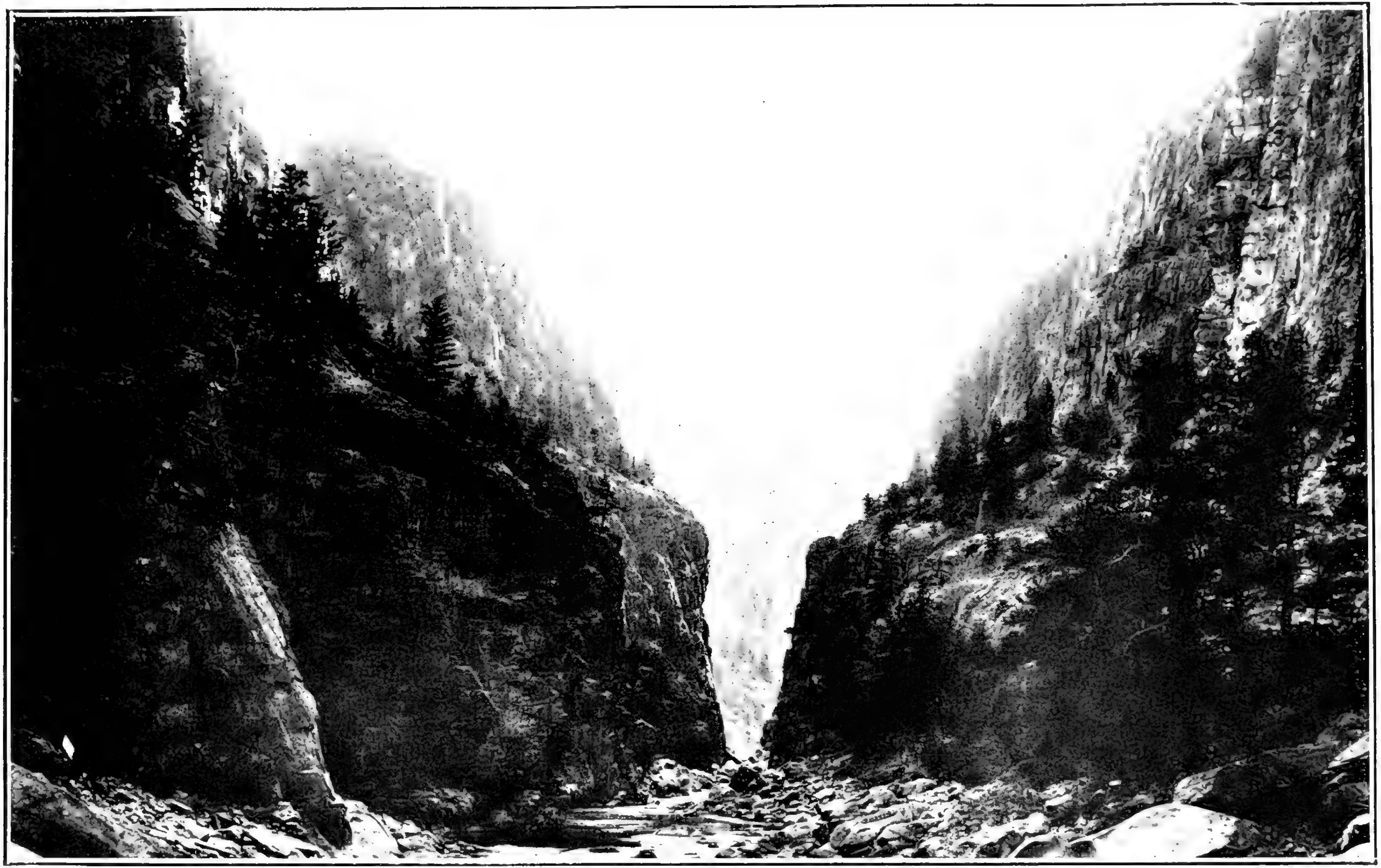
The fund probably reached its maximum in 1903, and the annual increments may be expected to be steadily diminished. If, however, it is assumed that the proceeds for the current fiscal year of 1905 are $5,000,000, there will be available by June 30, 1905, in round numbers, a total of $28,000,000.

The following table gives the names of the States and Territories from which the fund is derived, these being arranged in numerical order, Oregon, the State from which the largest portion of the fund has come, being placed first on the list. The last in order is Nevada. Opposite the name of each State and Territory is given the aggregate amount derived up to and including June 30, 1904, and also the restricted portion of the fund, or 51 per cent, this being accepted as the meaning of that portion of the Reclamation Act which declares it to be the duty of the Secretary to expend the major portion of the fund in the State in which it arose.

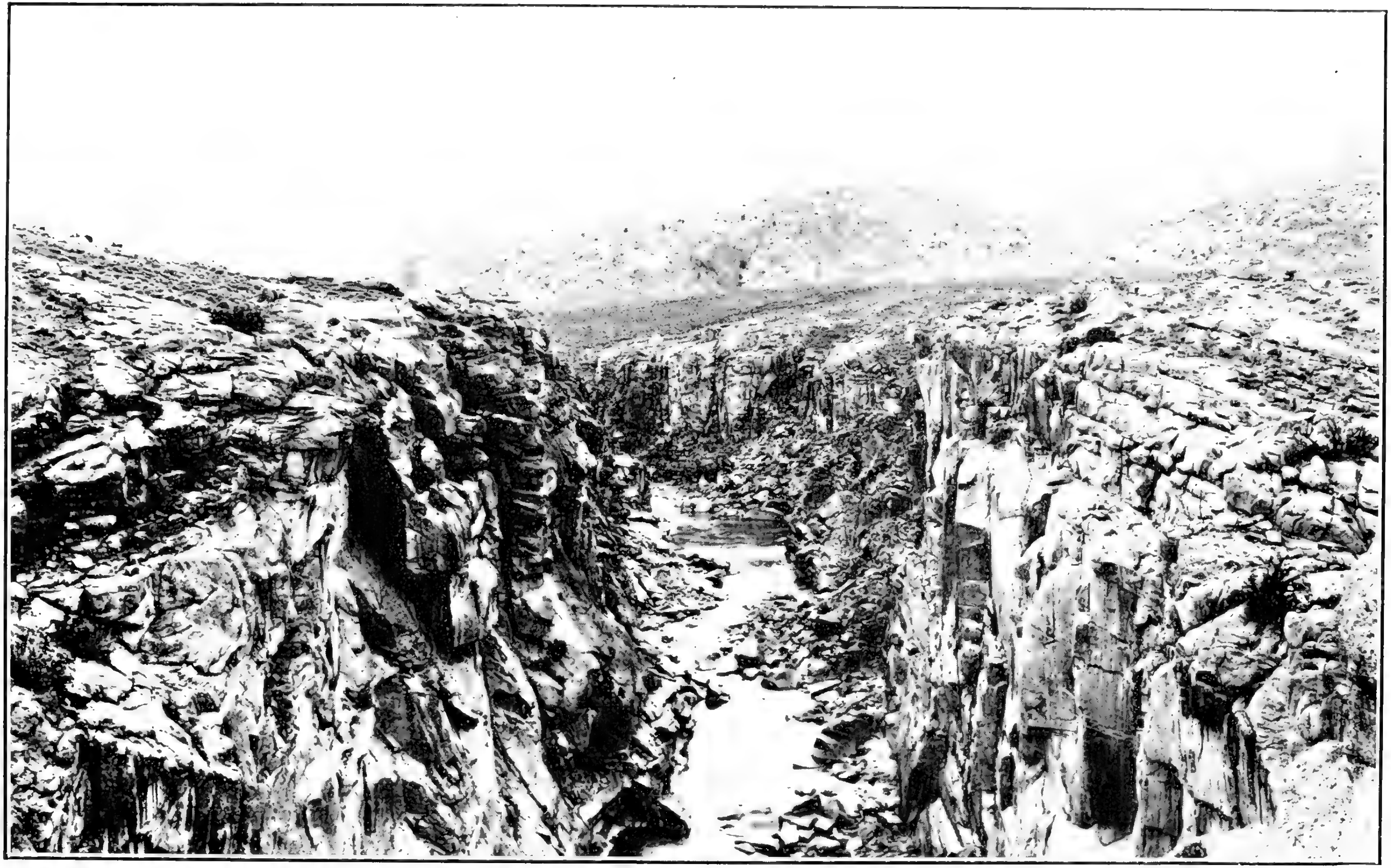
A glance at this table shows that as a rule the States where irrigation is most needed have furnished the least amount of money. This might be expected, as these States are arid in character and the lands are not readily disposed of.

Funds available under the reclamation law on June 30, 1904.

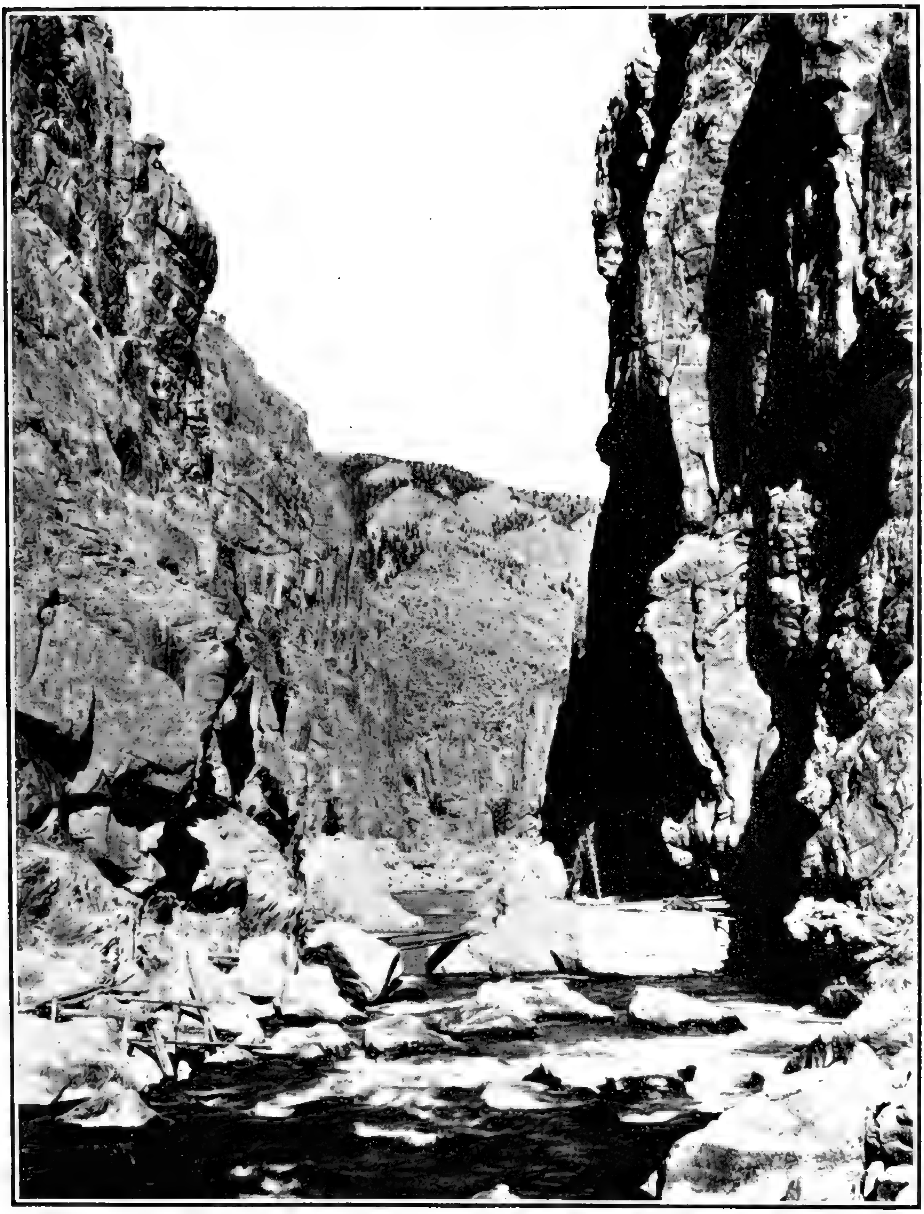
State or Territory.	Aggregate.	Restricted portion, or 51 per cent.
Oregon	$4,230,659.75	$2,157,636.47
North Dakota	3,406,100.14	1,737,111.07
Washington	2,735,362.98	1,395,035.12
Oklahoma	2,552,137.33	1,301,590.04
California	1,971,908.21	1,005,673.19
Montana	1,749,002.90	891,991.48
Idaho	1,645,529.55	839,220.07
Colorado	1,591,167.56	811,495.46
Wyoming	875,253.88	446,379.48
South Dakota	742,780.60	378,818.11
Nebraska	477,973.42	243,766.44
New Mexico	420,202.26	214,303.15
Utah	302,351.03	154,199.02
Arizona	166,403.86	84,865.97
Kansas	97,849.58	49,903.28
Nevada	48,153.41	24,558.24
Total	23,012,836.46	11,736,546.59



SHOSHONE CANYON, WYOMING, LOOKING UPSTREAM TOWARD THE SHOSHONE DAM SITE. SHOSHONE PROJECT.



LOOKING UP NORTH PLATTE RIVER TOWARD PATHFINDER DAM SITE, WYOMING. PATHFINDER PROJECT.



DETAILED VIEW OF SHOSHONE DAM SITE, SHOSHONE, WYO., LOOKING DOWNSTREAM.
SHOSHONE PROJECT.

MALHEUR DAM SITE, ON THE MALHEUR RIVER, OREGON. MALHEUR PROJECT.

The list below gives the principal projects in each State which, from present knowledge, appear to be most desirable for pushing to completion. Some of these have been definitely approved by the Secretary of the Interior and others are in various stages preliminary to such approval. The steps leading up to the adoption of a project are about as follows:

First, a reconnaissance is made which determines in a general way the desirability of making a definite survey. When this survey is well advanced or has been completed the project is brought to the attention of the Secretary for tentative approval, and authority is obtained for further detailed investigation and for the acquisition of lands or rights which may be needed. The next step is generally the completion of detailed drawings and specifications. The whole matter is then referred by the chief engineer to a project board for careful consideration and report.

Principal projects under consideration.

State or Territory.	Project.	Acres irrigable.
Arizona	Salt River	160,000
California	Yuma	85,500
Colorado	Gunnison	100,000
Idaho	Minidoka	130,000
Kansas	Arkansas	10,000
Montana	Milk River	60,000
Nebraska	North Platte	100,000
Nevada	Truckee	200,000
New Mexico	Hondo	10,000
North Dakota	Fort Buford	60,000
Oklahoma	Red River	40,000
Oregon	Malheur	90,000
South Dakota	Bellefourche	60,000
Utah	Utah Lake	60,000
Washington	Palouse River	100,000
Wyoming	Shoshone	160,000

The estimated cost per acre of this reclamation ranges from $20 to $30 and averages about $25.

In addition to the principal projects above listed reconnaissance surveys are being carried on in each of the 13 States and 3 Territories, and alternative projects are also being examined with a view to construction if the principal projects are for any reason found to be impracticable. It is proposed to have these alternative projects carefully examined and ready for construction as soon as the principal projects are out of the way. The following paragraphs give briefly the present stage of knowledge concerning each of the principal projects:

Arizona.—The Salt River project contemplates the storage of water

for irrigating approximately 160,000 acres of land and the developing of pumping facilities for an additional acreage. The cost will probably be about $20 per acre, and ultimately from $3,000,000 to $4,000,000 will be expended.

California.—The Yuma project on the lower Colorado River as now outlined involves the reclamation of 85,500 acres at a cost of $35 per acre, the land being on both sides of the river, in California and Arizona.

Colorado.—The Gunnison project contemplates the reclamation of 100,000 acres of land in the Uncompahgre Valley, at a cost of about $25 per acre. This land is largely in private ownership. The project involves the building of a tunnel 6 miles long from Gunnison River.

Idaho.—The Minidoka project is designed to reclaim 130,000 to 130,000 acres of vacant public land on both sides of Snake River, at a cost of $26 per acre. This is to be accomplished by the construction of dam and canals and development of the gravity and pumping systems.

Kansas.—Along Arkansas River it is probable that water can be pumped from the underlying gravels. Investigations have been made which indicate that considerable development of private lands may take place under the terms of the reclamation act.

Montana.—The Milk River project is designed to reclaim nearly 60,000 acres of land, mostly public, and located mainly on the south side of Milk River, east of Malta, Mont. Water will be stored in reservoirs. The cost will be from $20 to $25 per acre.

Nebraska.—The North Platte project is designed to reclaim an undetermined area on both sides of North Platte River, in both Wyoming and Nebraska. Water will be stored in Wyoming and canals built, heading in the State. Most of the land is now in private ownership. The cost of reclamation will probably be between $30 and $35 per acre.

Nevada.—The Truckee project, now under construction, will reclaim upward of 150,000 acres, at a cost of about $26 per acre. There are a number of ramifications which are yet to be worked out, and these may result in a larger development.

New Mexico.—The Hondo project, in the vicinity of Roswell, will irrigate about 10,000 acres, a portion of which is in private ownership. The cost will be upward of $25 per acre. Water is to be obtained from flood storage in a reservoir to be constructed on the north side of Hondo River.

North Dakota.—The Fort Buford project is designed to reclaim 60,000 acres on the west side of Yellowstone River, in Montana and North Dakota, at a cost of about $30 per acre. Most of this land is in private ownership.

Oklahoma.—In this Territory reconnaissance has shown that water

may be stored on the north fork of Red River, and it is believed that further exploration will show that there are lands which can be profitably irrigated by this stored water, at a cost of not to exceed $20 per acre.

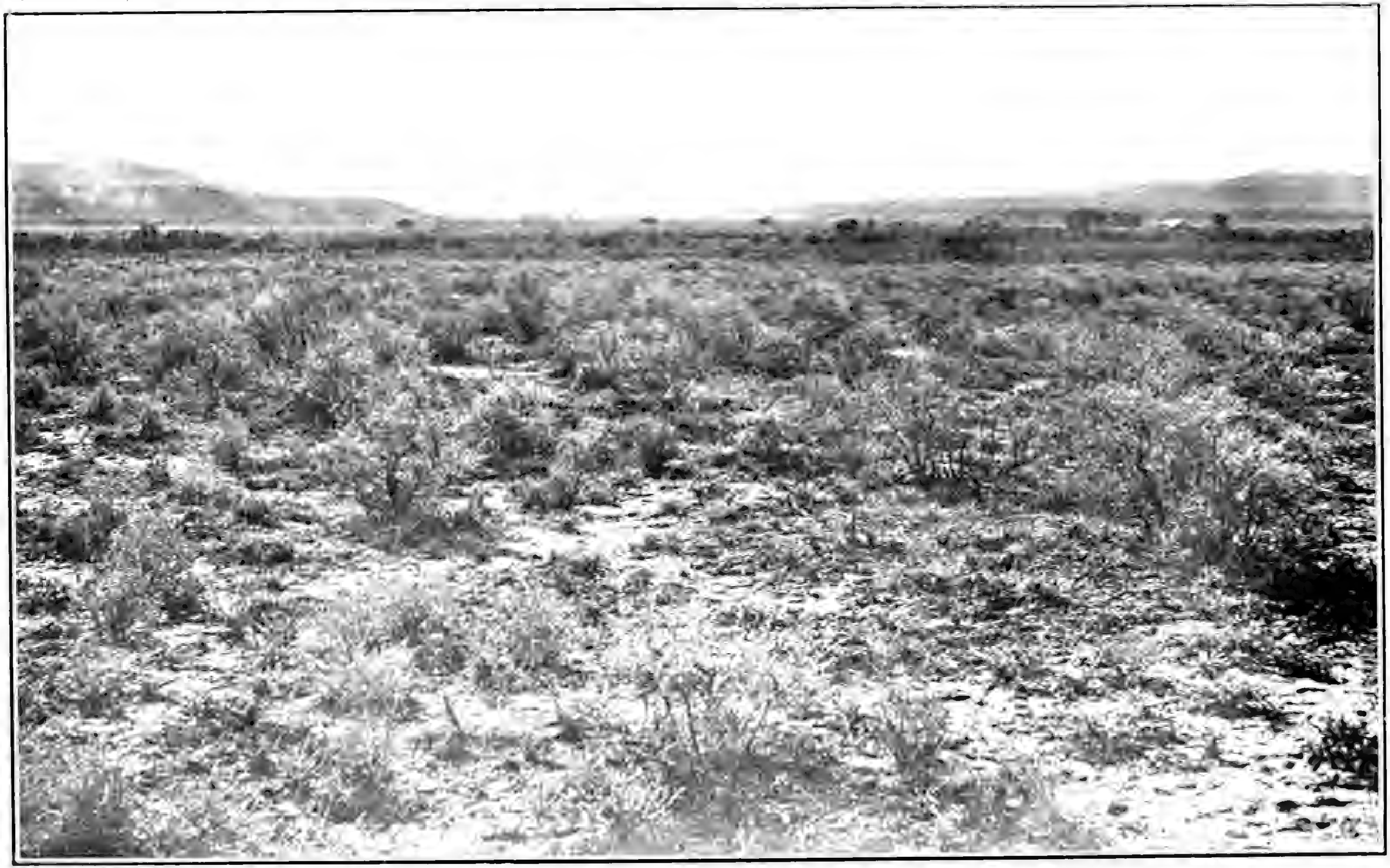
Oregon.—The Malheur project, on both sides of Malheur River, west of Ontario, will reclaim, by storage of flood waters of Malheur River, about 90,000 acres, at a cost of about $30 per acre.

South Dakota.—The Bellefourche project contemplates the reclamation of 60,000 acres of arid land, largely public, situated northerly from the Black Hills, by the storage of flood waters of Bellefourche River. The cost will be about $30 per acre.

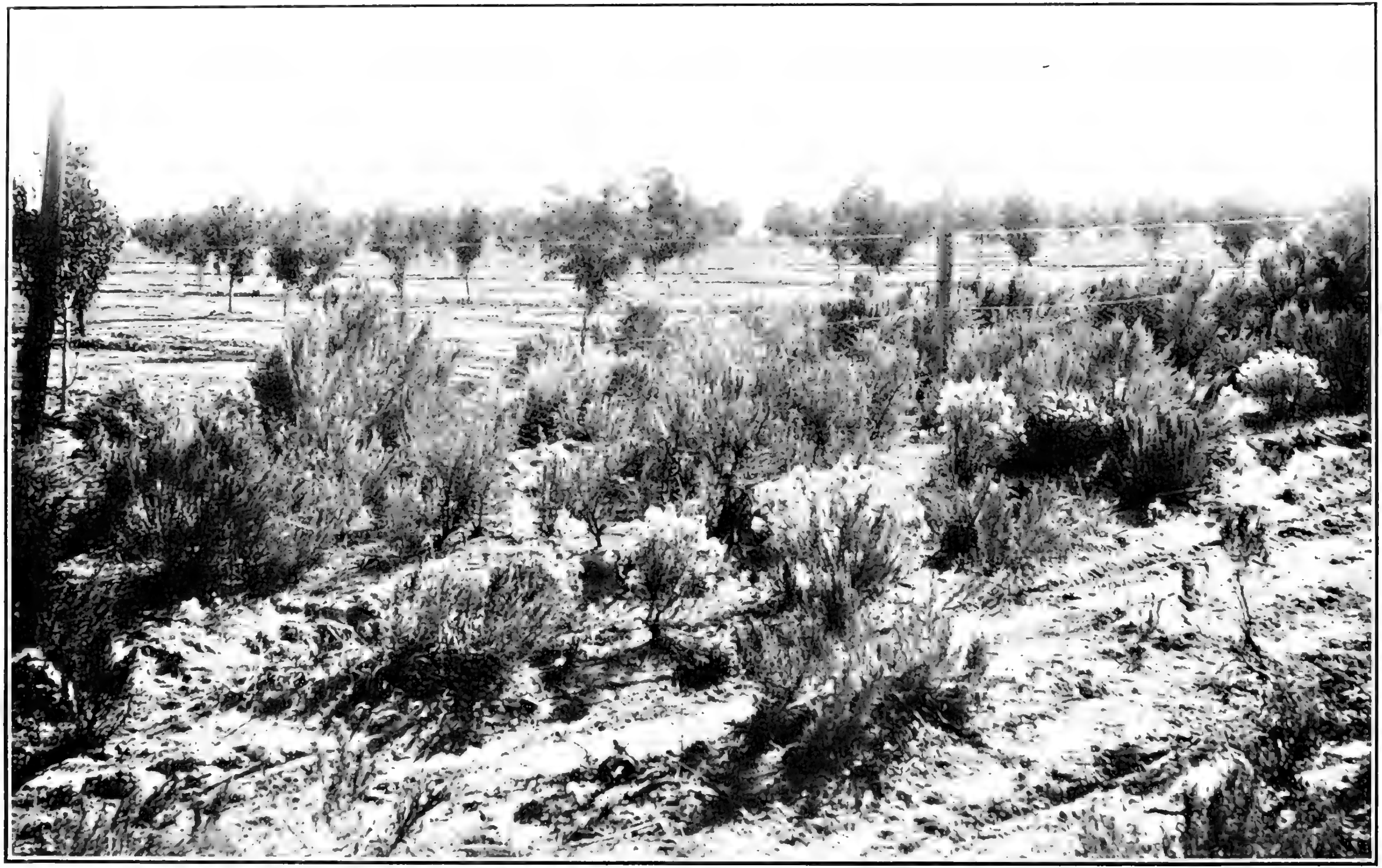
Utah.—The Utah Lake project contemplates the utilization of waters tributary to Utah Lake and the reduction of evaporation losses by drawing down the lake. It is possible that 60,000 acres may be reclaimed, at a cost of $35 per acre.

Washington.—The Palouse project is for the redemption of arid lands near Pasco by storage in Washtucna reservoir. Possibly 100,000 acres, mainly in private ownership, can be reclaimed, at a cost of $30 per acre.

Wyoming.—The Shoshone project is designed to reclaim 160,000 acres of public land in the Bighorn basin, north of Shoshone River. Water will be stored and diverted at a cost of $25 per acre.



LOOKING UP COTTONWOOD CREEK IN THE HARPER RESERVOIR SITE, OREGON. MALHEUR PROJECT.



PEAR ORCHARD ON THE ROCKEFELLER RANCH, ON DEAD OX FLATS, OREGON. MALHEUR PROJECT.

THE YUMA RECLAMATION PROJECT.[a]

By J. B. Lippincott, *Supervising Engineer.*

Under the provisions of the Reclamation Act of 1902[b] all the public lands along the Colorado River from the Grand Canyon to the Mexican line were withdrawn, pending a general investigation. Surveys were at once begun of this district and data are now in the possession of the Secretary of the Interior relative to all projects therein. It is estimated that there are between 300,000 and 400,000 acres of irrigable valleys between the points named, immediately adjacent to the river and exclusive of irrigable lands in interior valleys removed from the river. There are also 92,000 acres of mesa lands near Yuma suitable for the production of citrus fruits, that may be reached by pumping from the valley canal systems.

It has been decided that the proper point of beginning for the reclamation of this vast area is in the immediate neighborhood of Yuma. This enterprise does not include or interfere with the irrigation of private lands by individuals and corporations in the vicinity of Imperial, and there is no apparent reason why there should be any friction between these irrigation systems and those resulting from the construction of this Federal work.

During the winter season of 1903–4 the reclamation service made surveys for the irrigation of the valley lands of the Colorado and Gila rivers in the immediate vicinity of Yuma, Ariz., and the Yuma Indian Reservation in California, looking toward the utilization of the Colorado River for their water supply. These surveys included the making of a topographic map, on the scale of 100 feet to the inch, at the Laguna dam site and soundings for bed rock and foundations at that point. On the California side of the river, along

[a] Reprinted, by permission, from Outwest, San Francisco, June, 1904.

[b] It is provided among other things in this act that water may not be furnished by the Department for the irrigation of more than 160 acres belonging to any one individual, whether the lands are filed upon subsequent to their withdrawal under the Reclamation Act or are in private ownership under previous filings. Also, that water so supplied can be furnished only to parties residing on the lands or in their immediate neighborhood.

the route to be occupied by a possible canal, a map has been made on the scale of 100 feet to the inch with a small contour interval. On the Arizona side of the river a map has been made, on the scale of 100 feet to the inch, from the Laguna dam site to Yuma along the canal line, and in addition a number of angle-line surveys have been run for the exact determination of the location for the canal. Below Yuma transit surveys have been made for the location of the canal. At the crossing of the Gila River a map has been drawn on a scale of 100 feet to the inch, and soundings made for bed rock. Preliminary location surveys have been made for a complete set of levees from the Laguna dam site to the Mexican line, on both sides of the Colorado River, and also on each side of the Gila River. A drainage system has been projected upon the topographic maps which have been made of the entire district to an elevation of 150 feet above river level, and to the scale of 2 inches to the mile. Surveys have been made preliminary to estimates for pumping plants for irrigation and draining. A consulting electrical and mechanical engineer has examined the ground and made plans and estimates therefor.

A board of six consulting engineers has been through the estimates of the engineers in charge in detail, and the report which is submitted is the result of the deliberations and best judgment of all these men, and all estimates and plans have been brought to the complete satisfaction of each person.

In the Yuma Indian Reservation on the California side of the river it is estimated that there will be within the levees 16,000 acres, and on the Arizona side it is estimated there will be 91,000 acres under the system, making a total of 107,000 acres. Of this area it is estimated that 5,000 acres next to the Mexican line in Arizona will be subject to overflow in such a way as to temporarily exclude them from the irrigable areas, and in addition a small percentage of the remaining lands are known to be in sand dunes that will be above the level of the canal lines. In all, it is estimated that on both sides of the river there will be a total of 86,700 acres of irrigable land, of which 73,100 acres are in Arizona. The water supply of the Colorado River is adequate for the irrigation of this area.

A number of different designs for the diversion weir have been estimated upon in the study for the most economical type that may be built in safety at this point. Several different locations have also been examined to determine the best place for this structure, bed rock having been explored for, with diamond-core drilling machinery, at all possible dam sites between Yuma and Picacho. As a result of these explorations, the Laguna weir site has been selected as the most desirable one for the construction of a weir to serve the lands near Yuma, a high dam and high-line canal being considered

RELIEF MAP OF THE YUMA PROJECT.

impossible. The type of weir selected is one that has been tried during the last fifty years at numerous places in India and Egypt under similar conditions, three dams having been constructed on the Nile River within the past fifteen years on practically this same plan, all having served their purpose efficiently and being in operation to-day. This type of weir consists of a loose rock structure with a paving of stones 2 feet in thickness on the downstream slope, the structure being tied together with three parallel walls of concrete run longitudinally between the granite abutments on the two sides of the river, and the entire structure being further made secure by an apron of loose rock pitching 10 feet in thickness and 50 feet in width at the lower toe of the dam below the sloping pavement. The height of this weir is to be 10 feet above low water and the slope of the downstream side is 12 feet horizontal to 1 foot vertical, with the 50-foot apron below. The design calls for the upper core wall of concrete to rest upon a row of sheet piling driven into the bed of the river.

The handling of the silt of the Colorado is one of the most difficult features of this undertaking. It is known that its amount is very large. The river is on a grade of approximately 1 foot to the mile above the Laguna weir site, so that this weir, 10 feet high, will make a settling basin of relatively quiet water approximately 10 miles in length above it. At each end of the weir, and constructed in solid granite rock, will be a sluiceway 400 feet wide on the Arizona side and 40 feet wide on the California side with provision for its enlargement to 200 feet when desired, and excavated to the depth of 2 feet below low water in the river. These sluiceways will be closed by large gates operated mechanically. The diversion canals will take their water above these gates from the sides of the sluiceways. The area of these sluiceways being so great, the water movement toward the canal will be slow and most of the sediment will be deposited before reaching the canal intake. When this has accumulated to a considerable extent, the sluice gates will be opened, and it is estimated that their capacity will be approximately 20,000 cubic feet per second. This great volume of water passing through the sluiceways when the gates are opened will carry out with it the sediment deposited above the intake of the canal. The ordinary low-stage flow of the Colorado River is from 3,000 to 4,000 cubic feet per second; so the capacity of these sluiceways will be about five times the low-water flow of the river. These figures are given for purposes of comparison only. As the result of a number of experiments it has been found that the principal quantity of silt is carried along near the bottom of the river, and that the surface water is relatively free from sediment. It is planned, therefore, to take the

water into the canals by a skimming process over a long row of gates, so that the entire capacity of the canal can be furnished by drawing but 1 foot in depth of water from the surface of the river. Every portion of this weir and headworks, as designed, would be of rock, concrete, or steel, with the exception of the sheet piling, which will be driven entirely below the water level, and so will not decay. Every portion of the weir will be what is known as permanent construction. Such character of work will, of course, be expensive, but it has been proved to be sound economy to build in this way.

The capacity of these canals at their intakes will be 1,600 cubic feet per second on the Arizona side, and 200 cubic feet per second on the California side. The amount of silt that would be daily delivered into the Arizona Canal, if diversion were made directly from the stream, would approximate 17,000 cubic yards of wet mud by volume. It is not believed to be possible for a canal to continuously operate successfully for the irrigation of lands along the valleys of the Colorado River unless some very substantial arrangements are made at the headworks for the handling of silt, and this is believed to be a justification for the expenditure proposed for these headworks; also the water must be held to a fixed level at the canal heading for all stages of the river. This structure will cost approximately $1,000,000. It is not considered possible to remove all of the silt from the water, but the canals have been designed so that the velocities will be sufficient to convey through to the fields the light material entering the canals from the intake.

Careful study has been made of the existing canals in the vicinity of Yuma and Imperial to determine the shape that they naturally assume, and the roughness of the bottom and sides, which tends to retard the velocity. Based upon these data, the canals have been so designed as to carry water at a higher velocity throughout than will be found in the settling basins above their head, and of such velocity as will permit of a minimum loss by seepage and evaporation. The gates and drops of these canals and the Yuma bridges are designed as steel concrete structures. A distribution system has been estimated upon to furnish water to each 160-acre tract. There will be small areas of land in the upper Gila Valley, and below Yuma, that will have to be served by pumping plants, lifting the water from 5 to 7 feet. The power for doing this will be furnished from a water-power plant to be erected above Yuma at a drop in the main canal. This power plant will also be used in connection with the drainage system.

One of the most difficult problems in connection with this project is the crossing of the Gila River. It has been considered necessary to make this perfectly safe, and for this purpose a structure has been designed that will cross beneath the bed of the river, the top to be

several feet below the lowest point of the stream bed. This structure will be of steel and concrete, some 3,000 feet in length. It will be an inverted syphon consisting of four concrete pipes 10 feet in diameter reinforced with steel rods.

Because of the annual rise of the Colorado River, a large portion of the lands along this stream are subject to annual overflow, which practically prevents residence thereon, as well as the farming of them, without protective works. The levee, therefore, is considered an essential feature of the enterprise. The shape of levee adopted is one that has been developed by years of experience along the Mississippi River. It will have a slope of 3 feet horizontal to 1 foot vertical on the water side, and $2\frac{1}{2}$ feet horizontal to 1 foot vertical on the land side; it will be 8 feet wide on top, and be built 5 feet above the highest water marks of the year 1903. These levees will be 4,000 feet apart (one on each side) along the Colorado River, and 3,200 feet apart along the Gila River.

Because these lands are so flat, and the level of the water in the ground so near the surface, it is considered necessary, for their permanent safe irrigation, to supply a drainage system. A main drainage canal has been designed to run through the central portion of the areas to be irrigated, and when possible the natural drainage lines of the country will be utilized, deepening them with a steam dredger to such depth that they will carry off the water returning from irrigation or seeping through the levees during the high-water stage of the river.

When lands in any district tend to become alkaline they may be connected, by means of local drainage canals, with this main drain, and in this manner they could be kept free from alkali by holding down the level of the ground water. During the greater portion of the year, when the river is low, this drainage water would be discharged into the stream, but when the river is in flood its elevation will be such as to prevent a discharge into it from the drains. A pumping plant has therefore been designed to lift the drainage waters over the levees during the flood period of the river to prevent the lands becoming water-logged.

The whole system, as planned above, is one looking to the permanent reclamation of this district by means of irrigation, levee, and drainage works. All portions of the system to be made of steel, concrete, or earthwork.

The reports of the Department of Agriculture on the character of the soils of this valley, as well as past farming experience, indicate that they are exceedingly fertile. The silt of the Colorado River, all of which can not be removed at the headworks, has high fertilizing properties. Under these conditions, and with proper handling of the system, the valley should be perpetually fertile.

The entire cost of this enterprise, providing all the area is irrigated which is indicated above, will amount, according to the estimate, to about $35 per acre irrigated. It is entirely possible, however, that as the construction work proceeds this cost may be somewhat increased or lessened, although an effort has been made to cover all contingencies, and the estimates of cost have been liberal. The price will range near $35 per acre, this to be paid for according to the provisions of the reclamation act and regulations of the Secretary of the Interior, in ten annual installments after the first delivery of water. The annual charge for maintenance and supervision of this system will be very low and probably materially less than $1 per acre. There will be no charge for interest, profit, or taxes.

In order to keep the price as low as that estimated upon and to proceed with the construction of the works, it is necessary for all of the landowners of the portion of the district that is in Arizona, under the projected canal, to enter into an agreement with the Secretary of the Interior, through their local water users' association, for the payment for the water when it is delivered to them. The reclamation service has made the surveys and estimates required for the Secretary of the Interior concerning the costs and character of these works; but it is absolutely necessary for the local landowners to submit to the Secretary, through their local associations, the contracts for the acceptance of the water; and also to provide for the rights of way required for the levee, power plants, transmission lines, etc. This has been done, about 98 per cent of the entire area under the project now being subject to the reclamation act.

The Secretary of the Interior has set aside $3,000,000 of the reclamation fund for the construction of this project, contingent upon the action of the landowners of this valley and their entering into contracts with the Department, in accordance with the provision of the reclamation act passed June 17, 1902.

On March 15, 1905, bids for the construction of the dam were opened, and responsible bidders offered to build this structure for the amount estimated upon by the engineers.

THE EVIDENCE OF EVOLUTION.[a]

By Hugo De Vries.

The noble aim of university teaching is the lifting up of mankind to a higher appreciation of the ideas of life and truth. It has to cultivate the most intimate connection between theory and practice, between abstract science and actual life. Throughout the world of research this connection is felt to be the real stimulus of the work, the very basis of its existence. American universities and American science have developed themselves on this leading principle, and it is especially on this account that high admiration is given them by their European sisters. Nowhere in this world is the mutual concourse between practice and science so general as here, and nowhere is the influence of the universities so widely felt as in this country. Perfect freedom of thought and investigation, unhampered rights of professing and defending one's conviction, even if it should be wholly contrary to the universal belief, are the high privileges of all real universities. Wealthy citizens spend their possessions in the founding of such institutions, convinced that this is the best way of promoting public welfare. The Government liberally supplies funds for scientific research whenever its application to practical business is clear. Your system of promoting agriculture by means of experiment stations, of scientifically conducted farm cultures, of inquiries in all parts of the world, and of collecting, introducing, and trying all kinds of plants that might become useful crops is not only admired, but even highly envied by us Europeans.

It is not without hesitation that I have accepted the honorable invitation to speak before this renowned center of learning. The ideas to which I have been conducted by my experiments are to a large degree different from current scientific belief. But I have trusted to your willingness to listen to new facts and divergent convictions, and to your readiness to acknowledge whatever spark of truth might be found in them. Unbiased by prejudice, the calm air of the university and the enthusiasm of youth seeking only truth, and convinced that only pure truth can bring real progress, are the judges to which I gladly submit my conceptions.

My ideas have grown slowly, and have only reached their definiteness and full development under the protection of the high principles

[a] Convocation address, University of Chicago, September 2, 1904. Printed here by permission of the author.

of university freedom. I have needed nearly twenty years to develop them and to gather the evidence by means of which I hope to convince you. I kept my secret until some years ago, and worked only for myself. In this respect old universities, as ours are in Europe, have a distinct advantage over your young American institutions. With you all is sparkling and boiling, with us it is the quietness of solitude, even in the midst of a busy city. But your students and teachers are expected to show what they are doing, and to produce their results at short intervals. In Europe, on the contrary, we are trusted and left free even on this point. Hardly anybody has ever asked me what I was doing, and even those who from time to time visited my garden were content with what I could show them, without telling my real difficulties and my real hopes.

To my mind this is a high privilege. The solution of the most intricate problems often does not require vast laboratory equipment, but it always requires patience and perseverance. Patience and perseverance in their turn require freedom from all pressure, and especially from the need of publishing early and often unripe results. Even now I would prefer to spend this hour in recounting the obligations which the doctrine of evolution is under to such men as Lamarck and Darwin. I should like to point out how they have freed inquiry from prejudice and drawn the limits between religion and science; how they have caused the principle of evolution to be the ruling idea in the whole dominion of the study of the organic world, and how this idea has been suggestive and successful, comprehensive and hopeful during a whole century of continuous research. Everywhere it is recognized to take the leadership. It has been the means of innumerable discoveries, and whole sciences have been started from it. Embryology and ontogeny, phylogeny, and the new conceptions of taxonomy, paleontology of plants and of animals, sociology, history, and medicine, and even the life history of the earth on which we live, are in reality in their present form the products of the idea of evolution.

Instead of telling you of my own work, I should like to sketch the part which of late the scientists of the United States have taken in this work. Mainly in two lines a rapid advancement has been inaugurated in this country. I refer to the pure university studies and the work of the agricultural stations. Highly valuable is the application of science to agriculture in the improvement of races. Each of you knows how this artificial production of races of animals and plants was one of the great sources of evidence on which Darwin founded his theory. But at his time the available evidence was only very scanty when we compare it with the numerous facts and the improved methods which now are the result of half a century's additional work. America and Europe have combined in this line,

and the vast amount of facts, heaped up by numerous investigators and numerous well-equipped institutions, has produced quite a new basis for a critical review of Darwin's theory.

I have tried to combine all these too dispersed facts and to bring them together, in order to obtain a fuller proof for the main points of Darwin's conception. In one subordinate point my results have been different from those of Darwin, and it is this point which I have been invited by the kindness of your president to discuss before you.

Darwin's theory is commonly indicated as the theory of natural selection. This theory is not the theory of descent. The idea of descent with modification, which now is the basis of all evolutionary science, is quite independent of the question how in the single instances the change of one species into another has actually taken place. The theory of descent remains unshaken even if our conception concerning the mode of descent should prove to be in need of revision.

Such a revision seeems now to be unavoidable. In Darwin's time little was known concerning the process of variability. It was impossible to make the necessary distinctions. His genius recognized two contrasting elements—one of them he called sports, since they came rarely, unexpectedly, and suddenly; the other he designated as individual differences, conveying thereby the notion of their presence in all individuals and at all times, but in variable degrees.

Sports are accidental changes, resulting from unknown causes. In agricultural and horticultural practice they play a large part, and whenever they occur in a useful direction they are singled out by breeders and become the sources of new races and new varieties. Individual differences are always present, no two persons being exactly alike. In the same way the shepherd recognizes all his sheep by distinct marks, and to find two ears in a field of wheat which can not be distinguished from one another by some peculiarity is a proposition which everybody knows to be impossible. Many highly improved races of forage plants and agricultural crops have been produced by intelligent breeders simply on the ground of these always available dissimilarities. They can be selected and accumulated, augmented and heaped up, until the new race is distinctly preferable to the original strain.

In ordinary agricultural breeding, however, it is very difficult to distinguish sharply between these two principles. Moreover, for practical purposes, this distinction has no definite use. The practice of selection is nearly the same in both cases, and, besides hybridizing, with which we are not now concerned, selection is as yet practically the only means for the breeder to improve his races. Hence it came that at Darwin's time there was no clear distinction between the two types of variations, at least not to such an extent that a theory of the origin of species could confidently rely upon it.

Quetelet's celebrated law of variability was published only some years after the appearance of Darwin's Origin of Species. Variability seemed until then to be free from laws, and nearly everything could be ascribed to it or explained by it. But the renowned Belgian scientist showed that it obeys laws exactly in the same way as the remainder of the phenomena of nature. The law which rules it is the law of probability, and according to this law the occurrence of variations, their frequency, and their degree of deviation can be calculated and predicted with the same certainty as the chance of death, of murders, of fires, and of all those broad phenomena with which the science of sociology and the practice of insurance are concerned.

The calculations of probable variations based on this most important law did not, however, respond to the demands of evolution. Specific characters are usually sharply defined against one another. They are new and separate units more often than different degrees of the same qualities. Only with such, however, Quetelet's law is concerned. It explains the degrees, but not the origin, or new peculiarities. Moreover, the degrees of deviation are subject to reversion to mediocrity, always more or less returning in the progeny to the previous state. Species, on the contrary, are usually constant and do not commonly or readily revert into one another. It is assumed that from time to time specific reversions occur, but they are too rare to be comparable with the phenomena which are ruled by the law of probability.

A thorough study of Quetelet's law would no doubt at once have revealed the weak point in Darwin's conception of the process of evolution. But it was published as part of a larger inquiry in the department of anthropology, and for years and years it has been prominent in that science, without, however, being applied to the corresponding phenomena of the life of animals and of plants. Only of late has it freed itself from its bounds, transgressed the old narrow limits, and displayed its prominent and universal importance as one of the fundamental laws of living nature.

In doing so, however, it has become the starting point for a critical review of the very basis of Darwin's conception of the part played by natural selection. It at once became clear that the phenomena which are ruled by this law, and which are bound to such narrow limits, can not be a basis for the explanation of the origin of the species. It rules quantities and degrees of qualities, but not the qualities themselves.

Species, however, are not in the main distinguished from their allies by quantities nor by degrees; the very qualities may differ. The higher animals and plants are not only taller and heavier than their long-forgotten unicellular forefathers; they surpass them in large numbers of special characters, which must have been acquired by their ancestors in the lapse of time. How such characters have been brought about is the real question with which the theory of

evolution is concerned. Now, if they can not be explained by the slow and gradual accumulation of individual variations, evidently the second alternative of Darwin's original proposition remains. This was based on the sports, on those rare and sudden changes which from time to time are seen to occur among cultivated plants, and which in these cases give rise to new strains. If such strains can be proved to offer a better analogy to real systematic species, and if the sudden changes can be shown to occur in nature as well as they are known to occur in the cultivated condition, then in truth Darwinism can afford to lose the individual variations as a basis. Then there will be two vast dominions of variability, sharply limited and sharply contrasted with one another. One of them will be ruled by Quetelet's law of probability and by the unavoidable and continuous occurrence of reversions. It will reign supreme in the sciences of anthropology and sociology. Outside of these, the other will become a new domain of investigation, and will ask to be designated by a new name. Fortunately, however, a real new designation is not required, since previous to Darwin's writings the same questions were largely discussed and since in these discussions a distinct name for the sudden and accidental changes of species into one another was regularly used. At that time they were called "mutations," and the phenomenon of mutability was more or less clearly distinguished from that of variability in a more limited sense. Especially in France a serious scientific conflict raged on this point about the middle of the last century, and its near relation to religious questions secured it a large interest. Jordan and Godron were the leaders, and numerous distinguished botanists and zoologists enrolled themselves under their banners. They cleared part of the way for Darwin and collected a large amount of valuable evidence. Their facts pleaded for the sharp and abrupt delimitation of their species, and asked for another explanation than that which was derived from the ordinary, slow, and continuous variations.

Their evidence, however, was not complete enough to command the decision in their behalf. The direct proof of the sudden changes could not be offered by them, and they allowed themselves to be driven to the acceptance of supernatural causes on this account. Thereby, however, they lost their influence upon the progress of science, and soon fell into oblivion.

Instead of following this historical line, however, I have now to point out one of the weightiest objections against the conception of the origin of species by means of slow and gradual changes. It is an objection which has been brought forward against Darwin from the very beginning, which has never relented, and which often has threatened to impair the whole theory of descent. It is the incompatibility of the results concerning the age of life on this earth, as pro-

pounded by physicists and astronomers, with the demand made by the theory of descent.

The deductions made by Lord Kelvin and others from the central heat of the earth, from the rate of the production of the calcareous deposits, from the increase of the amount of salt in the water of the seas, and from various other sources, indicate an age for the inhabitable surface of the earth of some millions of years only. The most probable estimates lie between twenty and forty millions of years. The evolutionists of the gradual line, however, had supposed many thousands of millions of years to be the smallest amount that would account for the whole range of evolution, from the very first beginning until the appearance of mankind.

This large discrepancy has always been a source of doubt and a weapon in the hands of the opponents of the evolutionary idea, and it is especially in this country that much good work has been done to overcome this difficulty. The theory of descent had to be remolded. On this point conviction has grown in America during the last decades with increasing rapidity. Cope's works stand prominent among all, and much valuable discussion and evidence has been brought together.

The decision, however, could only be gained by a direct study of the supposed mutations, but no distinct cases of mutability were at hand to provide the material. Discussions took the place of inquiry, and a vast amount of literature has broadly pictured all the possibilities and all the more or less plausible explanations without being able to give proof or disproof.

In this most discouraging state of things I concluded that the only way to get out of the prevailing confusion was to return to the method of direct experimental inquiry. Slow and gradual changes were accepted to be invisible or nearly so; mutations, however, would be clear and sharp, although of rare occurrence. I determined to start on a search for them, and tried a large number of species, partly native forms of my own country and partly from different sources. Each of them had to be tried as to its constancy, and large numbers of seedlings had to be produced and compared. The chance of finding what I wanted was of course very small, and consequently the number of the experiments had to be increased as far as possible.

Fortune has been propitious to me. It has brought into my garden a series of mutations of the same kind as those which are known to occur in horticulture, and moreover it has afforded me an instance of mutability such as would be supposed to occur in nature. The sudden changes, which until yet were limited to the experience of the breeders, proved to be accessible to direct experimental work. They can not yet in truth be produced artificially, but, on the other hand,

their occurrence can be predicted in some cases with enough probability to justify the trial. Color changes in flowers, double flowers, regular forms from labiate types, and others have been produced more or less at will in my garden, and under conditions which allowed of a close scientific study. The suddenness of the changes and the perfection of the display of the new characters from the very beginning were the most striking results.

These facts, however, only gave an experimental proof of phenomena which were historically known to occur in horticulture. They threw light upon the way in which cultivated plants usually produce new forms, but between them and the real origin of species in nature the old gap evidently remained.

This gap, however, had to be filled out. Darwin's theory had concluded with an analogy, and this analogy had to be replaced by direct observation.

Success has attended my efforts even on this point. It has brought into my hands a species which has been taken in the very act of producing new forms. This species has now been observed in its wild locality during eighteen years, and it has steadily continued to repeat the phenomenon. I have brought it into my garden, and here, under my very eyes, the production of new species has been going on, rather increasing in rate than diminishing. At once it rendered superfluous all considerations and all more or less fantastical explanations, replacing them by simple fact. It opened the way for further investigations, giving nearly certainty of a future discovery of analogous processes. Whether it is the type of the production of species in nature or only one of a more or less large group of types can not yet be decided, but this is of no importance in the present state of the subject. The fact is that it has become possible to see species originate, and that this origin is sudden and obeys distinct laws.

The species which yielded these important results is an American plant. It is a native of the United States, and nearly allied to some of the most common and most beautiful among the wild flowering plants of this country. It is an evening primrose, and by a strange but fortunate coincidence bears the name of the great French founder of the theory of evolution. It is called "Lamarck's evening primrose," and produces crowns of large and bright yellow flowers, which have even secured it a place among our beloved garden plants.

The most interesting result which the observation and culture of this plant have brought to light is a fact which is in direct opposition to the current belief. Ordinarily it is assumed that new species arise by a series of changes, in which all the individuals of a locality are equally concerned. The whole group is supposed to be modified in a distinct direction by the agency of the environmental forces. All individuals from time to time intercross, and are thereby assumed to

keep equal pace in the line of modification, no single one being allowed to go distinctly ahead of the others. The whole family gradually changes, and the consequence would be that the old form disappears in the same degree as the new makes its appearance.

This easy and plausible conception, however, is plainly contradicted by the new facts. There is neither a gradual modification nor a common change of all the individuals. On the contrary, the main group remains wholly unaffected by the production of new species. After eighteen years it is absolutely the same as at the beginning, and even the same as is found elsewhere in localities where no mutability has been observed. It neither disappears nor dies out, nor is it ever diminished or changed in the slightest degree.

Moreover, according to the current conception, a changing species would commonly be modified into only one other form, or at best become split into two different types, separated from one another by flowering at different seasons or by some other evident means of isolation. My evening primrose, however, produces in the same locality, and at the same time, from the same group of plants, quite a number of new forms, diverging from their prototype in different directions.

Thence we must conclude that new species are produced sideways by other forms, and that this change only affects the product, and not the producer. The same original form can in this way give birth to numerous others, and this single fact at once gives an explanation of all those cases in which species comprise numbers of subspecies, or genera large series of nearly allied forms. Numerous other distinct features of our prevailing classification may find on the same ground an easy and quite natural explanation.

To my mind, however, the real significance of the new facts is not to be found in the substitution of a new conception for the now prevailing ideas; it lies in the new ways which it opens for scientific research. The origin of species is no longer to be considered as something beyond our experience. It reaches within the limits of direct observation and experiment. Its only real difficulty is the rarity of its occurrence; but this, of course, may be overcome by persevering research. Mutability is manifestly an exceptional state of things if compared with the ordinary constancy. But it must occur in nature here and there, and probably even in our immediate vicinity. It has only to be sought for, and as soon as this is done on a sufficiently large scale the study of the origin of species will become an experimental science.

New lines of work and new prospects will then be opened, and the application of new discoveries and new laws on forage crops and industrial plants will largely reward the patience and perseverance required by the present initial scientific studies.

THE EVOLUTIONARY SIGNIFICANCE OF SPECIES.[a]

By O. F. Cook.

The theory that species came into existence as results of separate creative acts has given place to the belief that the diversity of organic nature has been attained by gradual transformation, but the unconscious influence of the older view remains very strong. Even scientific students of evolution still take it for granted that there should be species, and hope to solve the problem of evolution by finding special conditions or agencies which can make new species out of old ones.

Science is by no means exempt from the very human tendency to place a fictitious value upon rare and exceptional phenomena, and to overlook the significance of familiar facts. Between Linnæus and Darwin a century of careful descriptive study of plants and animals intervened before the everyday incident of variation was appreciated, and it came to be perceived that species might arise through progressive change, or evolution. Having once assumed, however, that evolution could explain the origin of species, we have taken to seeking for evolutionary causes in the out-of-the-way places of biology, forgetting that the very existence and constitution of species affords evidence of the most fundamental character regarding the nature of the evolutionary process.

Why are organisms grouped into species, instead of manifesting unlimited and indefinite diversity? After reviewing the multiplicity of organic types and the innumerable modifications possible for each, it seems superfluous to doubt that the possibilities of diversity are endless. And yet all higher organisms are associated in species, and such associations have existed, apparently, throughout the biological history of the earth. Each investigator in turn has persevered in the hope that in learning the origin of species he would unravel the secret

[a] Consists principally of a revision and combination of two articles, "Evolution Not the Origin of Species" (Popular Science Monthly, March, 1904) and "Natural Selection in Kinetic Evolution" (Science, April 1, 1904).

of evolution, but from every mechanical or environmental standpoint species remain as mysterious as ever.

A species is a species, not through the workings of any hidden cause of evolution, but because the component individuals breed together, and thus remain in interconnected, coherent whole. This is the familiar and obvious fact which has escaped the appreciation of specialists. The individuals of a species are alike, not because of any fixed law or mechanism of heredity, but because they are traveling together along the evolutionary pathway. When a species encounters an environmental obstacle, and is divided into two groups, the parts can then evolve separately and become different. Evolution is not shown in the becoming separate, but in the becoming different, and the process of gradual change would have continued if the original group had not been subdivided.

The policy of taking species for granted has been carried by some to the point of declaring that no satisfactory definition of species could be made, but this was only because they were attempting to combine two incongruous ideas, and failed to distinguish the species as the evolutionary unit of interbreeding individuals from the pre-evolutionary species of analytical classification, "founded on identity of form and structure." In nature, however, there is no identity of form and structure, and no such species as those into which the narrowly formal systematist subdivides his genera.

It is not possible to make a definition which will enable us to recognize species without studying them; but, on the other hand, it is entirely practicable to tell what species are, or how they are constituted. A species is nothing more nor less than a connected or coherent group of interbreeding organisms. Interbreeding may enable them to maintain a general similarity throughout the specific series, or there may be sexual and other diversification which subdivides the species into two or more distinct sexes or castes without intermediates.

Adherence to the notion that species means "identity of form and structure" brings hopeless confusion of evolutionary ideas. The fact that characters which have arisen among inbred domesticated plants and animals disappear in crosses with the prepotent wild stock has been taken to prove "the swamping effects of intercrossing" in general. The segregation of new variations is now commonly held to be essential for their preservation, in complete disregard of the fact that the inbreeding unavoidable in such segregation would weaken the organism and give it a fatal handicap in the struggle for existence. The original assumption of this theory is as erroneous as the final deduction. Instead of having, or tending to have, "identity of form and structure," it is a physiological advan-

tage for the members of the species to become more and more diverse, not in order to subdivide into more numerous species, but because diversity of descent increases the vigor of the individual organisms of which the species is composed.

Sexual and other diversification inside the species has continued to become more and more accentuated in hundreds of independent groups of plants and animals, and is everywhere recognized as a mark of greater organic perfection. Professor Weismann held that under constant external influences variation would not occur;[a] but the practical fact is that in the same species, and under the same general environments, variations not only occur, but are preserved, accumulated, and integrated into sexual differences, not by isolating a part of the species from the rest, but under conditions of free and continuous interbreeding. The differences between the sexes are commonly greater than those which separate the species and genera, or even than those which characterize the families and orders, showing most conclusively that such differences can arise and become established, even inside the species, and quite without segregation. But instead of having been appreciated as the most important agency and the most significant illustration of evolution, sex and symbasic interbreeding have continued to be regarded as obstacles, because they interfere with the fancied necessity of segregation.

Evolutionists, too intent on a practical explanation of the diversity of species, magnified the idea that organisms become adapted to environment, and disregarded the more fundamental fact that species are not by nature stationary, but have an independent motion of their own. This oversight brought us the impossible task of explaining how external conditions produce evolutionary changes, and prevented the perception that adaptations are due to external causes only as environment may influence the direction of the normal and necessary movement of the species.

That evolution is thus an active, universal, and truly physiological process is not considered in current theories, largely because thought and language have continued to follow the bias of the original Darwinian controversy in seeking in evolution an explanation of the origin of species, and in expecting, conversely, that an explanation of the origin of species would also explain evolution. Such a history greatly increases the difficulty of presenting this alternative view, that the multiplication of species is in no proper sense a result of evolution, but is due to entirely distinct causes more often antagonistic than favorable to evolutionary progress.

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[a] Weismann, A., 1893, The Germ Plasm, 463.

EVOLUTION VERSUS TAXONOMY.

The early evolutionists were all systematists deeply impressed by the vast complexity of organic nature, a sentiment which we may still indulge, since two centuries of labor have but made a beginning in the task of describing and assigning names to the millions of groups of organisms. Nevertheless, it is to be regretted that biological evolution was viewed and expounded so exclusively from the standpoint of the taxonomist. His interests are greatly at variance with those of the evolutionist, and the confusion of the two distinct lines of investigation has done much to perpetuate the erroneous identification of the origin of species with the process of evolution.

The evolution best appreciated by the taxonomist is one which produces species separable by definite and easily definable characters. He finds such species on islands and in other circumscribed regions, and infers that isolation is an important evolutionary factor, failing to perceive that the "constancy" of insular species is merely a uniformity made possible by the limited area of distribution, and hence usually absent in species of more extensive range.

The systematist is prone to believe that there has been more evolution in a genus of ten readily definable species than in another occupying the same geographical region, but consisting of only one species. For the evolutionist, however, the segregation of the numerous species means that the conditions are less uniformly favorable for the subdivided genus than for the other. Among fossil organisms, also, the more generalized the types the wider was the distribution, the separation of local genera and species following with less favorable circumstances or greater competition. Segregation multiplies species by separating groups of organic individuals, just as the ocean might form many islands from a partially submerged continent. Species are biological islands, but we do not go further in biology than in geography by the discovery that islands must be isolated. Isolation permits evolutionary progress to be made on separate lines, until the differences become of diagnostic utility to the systematist; but that isolation is responsible for the changes which bring about the divergence of characters is a deduction no more logical than that the differences of islands are due to the waters which separate them.

Too narrow zeal in the descriptive task has led many systematists to act on the assumption that the same amount of difference should everywhere receive the same taxonomic recognition, a method sometimes defended on the ground that all variations of form or structure indicate incipient species budding out from the parent stock, and sure to become separate groups like other now segregated types, a supposition quite unsupported by evidence. Far more rational and more secure would be the progress of systematic biology if recognition as

species were limited to groups of individuals separate in nature, regard being given to the completeness of segregation rather than to the amount of difference.

It is to be admitted, of course, that when specimens from a new locality offer tangible differences from any previously known, the working systematist must describe and name them as reprsenting new species. To crowd them into an old species by "emending the description," or by calling them a "variety," is to guess at an integration in advance of knowledge; while to refuse to unite "species," which have been shown to belong to a continuous series in nature, is to prefer technical fiction to biological reality. A coherent group of interbreeding individuals is the unit of evolutionary biology to which the term species finds its most proper application. The tendency of some systematists to refer also to intergrading unsegregated subdivisions of such groups as "species," shows how easily conventional taxonomic methods may obscure evolutionary distinctions.

CRITERIA OF SPECIFIC DISTINCTNESS.

Species differ, of course, in the variability of their characters, but, other things being equal, the uniformity of the individuals of a species might be expressed by a ratio between the range and the facilities for interbreeding. A widespread species of sedentary animals or plants will become locally diversified; more frequent intercommunication permits more uniform progress. A single species may have as great a variety of characters as a dozen related groups which have been segregated. Two species may be quite distinct and yet differ much less than the connected extremes of another. That a species differs in different parts of its range does not necessarily mean that a subdivision will take place; it means merely that characters are originating more rapidly than they spread over the whole species. The integrity of a species is not destroyed by "inconstancy" of characters, but because geographical or other barriers make a gap in the series.

The failure of the extremes of a widely distributed species to breed when brought together does not prove the attainment of specific distinctness nor the approach of it, since internal diversity does not weaken the species, but is an evolutionary advantage, and both extremes may continue to cross freely with the connecting forms which constitute the bulk of the species. Neither does the power to form fertile hybrids prove that two species occupying distinct ranges are one. Faith in such criteria is simply a remnant of the preevolutionary theory of the separate creation of species. The only way to ascertain that two groups of organisms are separate species is to find the

gap between them. Whether they will breed together or not, and whether the hybrids are fertile and vigorous, or weak, sterile, and aberrant, may indicate the period and degree of divergence of the types crossed, but affords absolutely no evidence as to whether the series to which they belong in nature are continuous or interrupted. Specific distinctness is a question much more geographical than evolutionary. Evolution continues whether the species is divided or not; the divergence of the parts is rendered possible by the cessation of the interbreeding, which would otherwise maintain the coherence and relative uniformity of the undivided group.

SEGREGATION AND VITAL MOTION.

The systematist "separates" species because they are "different," but the evolutionary significance of species does not appear from formal descriptions of these biological islands; it lies in the fact that isolated groups of organic individuals universally acquire diagnostic differences. Isoation has furnished millions of these tests of the universality of biological motion, but it does not cause the motion. Evolution is independent of isolation, and without it has often brought about in the same species great diversity of sexes, castes, dimorphic and alternating generations of many species of plants and animals. Without evolutionary progress there would have been no species as we now know them, but the causes of the segregation of species are not causes of evolution; segregation merely permits this universal tendency to become more manifest. If it should be found that evolutionary divergences sometimes assist natural selection or physical barriers in the work of subdividing species, this would mean that evolution sometimes results in segregation, not that segregation causes evolution.

Evolution is a process of change in species; it is the journey of which individual variations are steps. Evolution changes the characters of species, but it does not originate species; it makes species different when segregation affords the opportunity.

Natural selection may assist geographical and other influences tending to the division of species, but it is not on that account a cause of evolution; it represents the determining aspect of the environment—the factors which influence the direction of the vital motion, but not those which induce the motion. Natural selection may explain differences between two species, but not the becoming different. It is an external incident or influence and not an active principle or agency of organic evolution. Adaptation is possible because there is a vital motion which can be deflected, not because the environment changes the characters of species. The river of evolution flows through the land of environment; the conformation of the valley

determines the course of the stream, but the water descends by its own gravity.

In the course of its progress the species explores the adjacent territory and follows the line of least resistance to the variations it is able to put forth. Changes are necessary to maintain the vitality of the species and also to keep it abreast of its environmental opportunities, and if no adaptive movement can be made it is still unable to remain stationary, but continues to change in characters indifferent to the environment, or even actually detrimental.

The species encounters obstacles and subdivides because it is in motion; the diversity of form arises because variations can no longer spread freely among the individuals of the species, not because the environment introduces new characters.

That species occupy definite regions of distribution has been taken by some to mean that the individuals are similar because they are molded by similar influences, but that this inference is wrong is shown both by the wide diversity of conditions under which some species exist, and by the even wider diversity of form and structure often found among the members of the same species, in the same environment. Similarity of conditions may permit plants and animals of different origins to develop similar variations, and to share, finally, the same adaptive characters, but identical conditions do not put an end to individual variations, nor to evolutionary progress.[a]

THE INFLUENCE OF SELECTION.

In denying that selection has any power to initiate or actuate developmental changes there is no intention to imply that it has not profoundly influenced the course of evolution in many groups. Indeed, it may be claimed that the kinetic theory[b] afforded the first concrete explanation of the workings of natural selection. Vital motion not only makes selective influence possible, but it meets the ancient and hitherto fatal objection to the doctrine of adaptation, since it shows how characters may originate and develop to the point of utility or harmfulness, where adaptive selection can take effect.

That there are species, varieties, mutations, or hybrids which differ in one, two, or three characters, as commonly asserted in discussions of Mendel's laws, is quite unwarranted by facts. The mention of a single peculiar character may suffice to designate a species or variety for taxonomic purposes, but in evolutionary studies it is careless to

[a] "Even sugar beets, the oldest 'selected' agricultural plants, are far from having freed themselves from the necessity of continuous improvement. Without this they would not remain constant, but would retrograde with great rapidity." DeVries, H., 1905, Species and Varieties, 109.

[b] Cook, O. F., 1901. A Kinetic Theory of Evolution, Science, N. S., 13:969.

forget that the diversity is general and multifarious, like that of individual apple trees or men. Evolution is a continuous summary or integration of this individual diversity, and is not a simple process, but highly multiplex, as much so, indeed, as the lines of descent in which the life of the species goes forward. A composite general direction is maintained by the species because the multitudinous strands of individual descent are bound together by interbreeding. The variations take place in particular threads, but evolution signifies rather the progressive change of the whole organic network.

The evolution of a new type means changes in many directions and of many kinds in the germ cells and in the various tissues and organs, as well as in the external form of the complex cell colony which we are accustomed to look upon as a single individual.

Each cell, tissue, organ, and feature is undergoing evolution, and for normal and permanent progress these manifold developments must keep together. When single lines or slender strands of descent are separated from the main network the congruence of type is lost. The normal variation and individual diversity of the species having been eliminated, the evolutionary coordination of cells, organs, and functions breaks down, and abrupt changes or aberrations of heredity appear. These degenerative mutations may not differ in their essential nature from normal variations, but the conditions of their appearance are abnormal, and the results often disastrous.[a] Mutations, like hybrids, are sometimes completely sterile, and they may have at the same time an increased vegetative vigor. The vegetative vigor of many mutative varieties of domesticated plants has doubtless delayed the recognition of their abnormal evolutionary status, though the abnormality of infertile hybrids has long been appreciated. It is paradoxical, indeed, that the increased vigor which accompanies normal variations and crosses should also attend degenerative changes, but there is room for this apparent contradiction in so complex and many-sided a process as evolution.

A domestic variety may be " improved " by the further increase of the one or two characters or qualities which render it valuable, but a new specific or generic type is the compound or resultant of many variations in many characters. By close selection, which restricts evolutionary progress to a narrow line of descent, a " single character " may push out farther in a decade than the natural multiplex evolution would carry it in a century or a millennium, but such a specialization weakens and unbalances the organisms, and is a process of degeneration rather than a constructive evolution. Selective inbreeding and other forms of isolation accentuate single characters, but the

[a] See Cook, O. F., 1904. The Vegetative Vigor of Hybrids and Mutations. Proc. Biological Society of Washington, 17: 83.

interbreeding of normally diverse individauls (symbasis) weaves new types out of the variations of many lines of descent.

All organisms are subject to selective influence in the sense that variations are rejected with a promptness proportional to their harmfulness in the given environment, but generally this leaves a very wide latitude of possible changes in which selection does not interfere. The instances are relatively rare in which existence becomes acutely dependent upon the development of some one characteristic or quality, and such narrow selection does not strengthen the type, but insures and hastens its extinction.[a]

The neglect of this distinction vitiates much evolutionary literature, both that which treats selection as an actuating "force" and that which rejects selection for "discontinuous variation" or "the mutation theory." It is true that many variations of inbred domesticated plants and animals are very abruptly discontinuous, and that such changes are not caused by selection, but these facts in no way militate against others equally obvious, that the natural evolution of new types is a relatively slow and gradual process, and that selection influences the direction of this continuous vital motion. The older selective hypothesis was only half erroneous. Selection does not set stationary organisms in motion, but it often guides spontaneous change. It does not explain evolution or vital motion in general, but it does explain adaptation, or motion in some particular direction, as when one species differs from its relatives in special characters which enable it to exist in a special environment. That all adaptations are mere coincidences is as improbable as that all characters represent useful adaptations.

Selection is not, as many "Darwinians" have maintained, the true, efficient, cause of evolution. The vital motion of species proceeds whether selection is operative or not. Species do not acquire characters from the environment, but merely in accordance with it. At any point in the evolutionary journey selection may determine whether certain characters shall be acquired or not. It is an obstacle in the environmental road over which the species would travel, instead of being the source of power of the organic automobile. Selection prevents motion in one direction, but permits advance in another. It explains why a particular character becomes accentuated in a particular species, but is no more a cause of the developmental progress of the species than the turns of the road are the motive power of the vehicle.

The hypothesis of selection as the active principle or causal agency of evolution became illogical and useless as soon as the inheritance of acquired characters was discredited. The first idea without the

[a] O. F. Cook, 1903, "Stages of Vital Motion," Popular Science Monthly, 63: 16.

second does not account for adaptations. The "selection" of Nageli, Weismann, and other believers in a "determining principle" or "hereditary mechanism" of evolution is a very weak substitute for the original Darwinian idea, since it is able to eliminate only the hopelessly unfit, but is quite without means of influencing the survivors.

Segregation enables species to attain differential characters, and selection assists their accommodation to environment, but both these possibilities rest on the more fundamental fact that organic evolution goes forward without external causation in groups of diverse, interbreeding individuals. If a species stood still selection could effect nothing except its partial extinction. In the recognition of a continuous and universal evolutionary motion the kinetic theory supplies the long-sought explanation of selective influence. Selection ceases to be a mysterious evolutionary cause, but retains a practical and easily comprehensible evolutionary function.

THE SPECIES A PROTOPLASMIC NETWORK.

The traditional illustration of organic descent by a tree with ever-dividing branches is entirely misleading as a suggestion of the nature of evolutionary processes, because individuals do not follow each other in simple series. Successive generations are connected by endless intergraftings of the lines of descent. A species may be treated systematically or statistically as an aggregation of individuals, and may be described by an averaging of the characters of these, but from an evolutionary point of view it does not exist as a species because of the possession of a certain complex of characters, but because the component individuals breed together; through this alone is the integrity or coherence of the species maintained. For evolutionary purposes we may think of the same species existing thousands of years hence, and with any or all of its characters changed.[a] It is not necessary even that the individuals of a species remain alike; in many unrelated natural groups extremely diverse sexes, castes, and "forms" remain associated in the same species and travel together on the evolutionary journey, sharing the same environment, but without any tendency to become "exactly alike." Moreover, we know that sexual and other diversities inside the species are not casual or accidental, but normal and advantageous, facts quite overlooked in static theories, which have viewed life from a narrowly systematic standpoint

[a] Cook, O. F., 1899, Four Categories of Species, American Naturalist, 33: 287. The "species" into which paleontologists arbitrarily divide geological series of organisms may be explainable by evolutionary progress alone, but the multiplication of the contemporaneous species of a given horizon is a different question.

and have argued that interbreeding is a hindrance to evolution in that it prevents the preservation of new characters.

The kinetic theory, on the contrary, ascribes the fact that organisms are everywhere bound up into species to a property of fundamental evolutionary importance, and interprets the multitudinous devices for maintaining the coherence of groups of interbreeding organic individuals and the equally general manifestations of sexual and other diversification inside specific lines, as due to the same requirement of protoplasmatic organization, an interlacing network of descent. Without cross-fertilization species would not cohere, but would split into numberless independent, diverging lines. This takes place with organisms long propagated asexually, whether artificially or in nature. For example, the genus Sphagnum, which very rarely produces spores, offers a multiplicity of varieties nowhere approached among mosses having normal sexual reproduction; but, notwithstanding so many differences in minute details, Sphagnum has remained a very compact, unprogressive group. Cross-fertilization prevents this type of diversification, but it need not on that account be supposed to impede evolutionary progress. Evolution is not merely a progressive diversification; it requires also a progressive synthesis of characters by the interbreeding of the individual members of specific groups.

That sexual reproduction is a substitute or improvement of multiplication by fission is another partial and misleading view which has contributed much toward the concealment of the causes of evolution. The division of cells is the only method of organic increase; conjugation is not multiplication, but serves as a preliminary stimulant to the necessary cell division. What is growth, for example, among the filamentous algæ, composed of chains of cells, is reproduction among the unicellular species where divided cells become separate individuals. Only among the simplest organisms, if anywhere, is indefinite reproduction possible without the assistance of conjugation.

The new science of cytology has made us aware that the division of cells is not a passive or a simple process, but is extremely active, complex, and varied. Living protoplasm is in motion, and the discovery that cell walls are not hermetically closed, but are perforated by delicate protoplasmic strands, lends strength to the belief of some biologists that protoplasm circulates, not only inside the individual cells, but through the entire organism. Conjugation may signify that such a circulation extends also throughout the species. Or, to vary the analogy, the net-like structure of protoplasm may be thought of as continuous, not only in the individual, but as binding together the whole species by the intercrossing of the lines of individual descent. As individual organisms will in different degrees endure

subdivision and are able to restore or regenerate the lost part, so species may survive a certain amount of segregation; but if too small a group of individuals be cut off, it perishes through the reproductive debility long recognized as inherent in inbred or narrowly segregated organisms. For taxonomy the tree motion of descent was sufficient as a means of indicating the history and affinities of species and higher groups, but evolution is a process which must be studied inside the species, and here the diagram of relationship is not dendritic, but reticular.

SYMBASIS A CAUSE OF EVOLUTION.

If reproduction by means of cell division is reckoned as an essential property of protoplasm, equally fundamental importance can scarcely be denied to the property called symbasis,[a] which requires this interweaving of numerous lines of descent and this simultaneous movement of organisms in specific groups. As organic complexity increases there is a greater necessity for cross-breeding, as evidenced by the accentuation of sexual diversity and by the decline of asexual propagation and of the power of regenerating lost parts. Organisms which have traveled farthest upon the evolutionary journey are most dependent upon symbasis. Nowhere among the higher animals, including many thousands of species of arthropods and vertebrates, is there known to be a long-continued series of nonsexual individuals.[b] In comparison with the higher animals, plants are but loose and unspecialized aggregations of cells, and yet among them also sexual differentiation has made great progress, and in some orders contrivances to insure cross-fertilization are highly developed.

The extent to which conjugation exists among the lower groups is not yet determined. That it may be omitted for many generations of a simple organism should not be taken to mean that it is entirely absent or has no importance, since among the higher animals, where

[a] Symbasis signifies etymologically a moving together or in company, and refers to the fact that organisms exist and make normal evolutionary progress in groups, rather than on simple or narrow lines of succession. The word may be used also in a physiological sense, to indicate a normal and advantageous range of interbreeding among the individuals of organic groups. It is to be distinguished on the one side from wide cross-breeding and on the other from narrow inbreeding, both of which produce inferior offspring and interfere with evolutionary progress. The confusion arising from the very frequent use of interbreeding in the contrary sense of inbreeding would also compel the introduction of a new and unambiguous term.

[b] Among the bees fertilization may be omitted for a single male generation, and among the plant-lice for several wingless generations, but such instances are admittedly exceptional and specialized.

cross-fertilization is recognized as indispensable, the growth of the body to maturity requires millions of cell divisions, each of which would mean a new generation in a unicellular species. The supposed absence of sexual reproduction in certain parasitic and saprophytic groups is a confirmatory exception in view of the obvious degeneration of such organisms.[a]

To the many speculations on the purpose of sex and cross-fertilization it can do no harm to add the conjecture that the presence of moderately diverse qualities of protoplasm facilitates cell division. Some have held that the function of sex is to assist evolution by producing variations, and others that it neutralizes variation by maintaining a stable average. From the kinetic point of view it appears that symbasis, as represented by the phenomena of sex and of cross-fertilization, is not an impediment to evolution nor a device to cause variation, but a means of communicating it. Variations appear without sex, and may even be accumulated, as by the adding of one bud variation to another in plants propagated by grafts or by cuttings, like the breadfruit, apple, and banana. Such progress is, however, slow and halting, and is accompanied by a decline in reproductive fertility. Symbasis not only sustains the vitality of organisms already evolved, but it is directly responsible for the upbuilding of the complex structure and vital economy of the higher plants and animals, and it builds the faster when by the differentiation of sexes two sets of variations can be accumulated.

To symbasis is due also the arrangement of organisms in the coherent groups called "species," or what may be termed the specific constitution of life. Conjugation is the means of symbasis, as division is of reproduction. Sexual and other dimorphism, and the numerous specializations, devices, and instincts by which cross-fertilization is secured, are aids to symbasis, just as the spore-sacs, ovaries, and placentæ facilitate reproduction. The phenomena of reproduction and those of symbasis are combined, perhaps inextricably, but all attempts at assigning them to a single cause or property have failed.

Cross-fertilization is commonly misunderstood to be merely an accessory of reproduction, and a negative factor in evolution, because it is supposed to conduce to the permanence of the specific type by averaging away the new characters which arise as individual variations. There is the amplest experimental evidence that cross-breeding is necessary to maintain the quality and efficiency of the

[a] Under a kinetic theory the existence of sexual reproduction and cross-fertilization in many fungi in which these processes are still unknown may be inferred from the simple fact that the individuals are grouped into well-defined species.

individual, but static theories[a] have led to the belief that evolutionary progress requires conditions unfavorable to the individuals of which species are composed, since under such conditions selection is most effective and abrupt variations are most striking and numerous. The alternative kinetic theory holds that cross-fertilization, as the active agency of symbasis, is a positive and primary factor of evolution, coordinate with variation itself. Symbasis is the multiplier of the evolutionary equation; it brings about the distribution and combination of individual variations into the resultant vital motion of the species. Evolution no longer appears as an abnormal or exceptional phenomenon, and it becomes clear that the conditions under which the species is most prosperous are also those which permit the most rapid evolutionary progress.

THE PREPOTENCY OF VARIATIONS.

The first corrollary of the law of symbasis is the prepotency of variations. The combination of variations not only permits the structure of the organism to be strengthened and rendered more efficient, but also gives prepotency, due to the opportunity of vital motion. Variant individuals being thus both vigorous and prepotent, it is easy to understand why diversity, and not uniformity, is the tendency of normally extensive species; changes are necessary and welcome, and the perpetuation of them does not require segregation. Numerous and well authenticated instances of distinctly prepotent variations

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[a] Static theories, under which species are held to be normally stationary, may be subdivided into two groups, those which look upon evolutionary progress as gradual and as actuated or carried along by natural selection, and those which treat the motion as discontinuous or saltatory and due, not to selection, but to abrupt variation or mutation. Selective theories, again, may hold either that the environment causes the desirable variations or "acquired characters," or they may imply the motion of a somewhat constant range of variability in species, which are thought of as growing out farther on one side because selection keeps them pared off on the other. Movement is thus ascribed variously to the direct action of the environment, to selective isolation, to abrupt transformation or mutation, or to some combination of these.

Under Haeckel's biogenetic law evolution appears as a resultant of (1) *palingenesis*, a positive hereditary tendency to repeat the ancestral form, and (2) *kenogenesis*, a negative, disturbing, adaptive influence located in the environment. The late Professor Hyatt summarized a similar view by characterizing heredity as *gentipetal* and environment as *gentifugal*, the one tending to make all individuals alike, the other causing difference and evolutionary progress.

The kinetic theory depends upon none of these supposed factors, but interprets vital motion as continuous, gradual, and self-caused, or inherent in the species, though the environment is thought of as influencing the direction of organic change. Selective influence is neglected altogether by still other theories, such as that of Naegeli, in which evolution is explained by an internal "hereditary mechanism," supposed to carry the species along in a definite direction.

are known, and such were taken by Mivart and other zoologists to prove that species do not originate by gradual change, but abruptly or by "extraordinary births," a view quite similar to the more recent theories of mutations,[a] but distinctly more practical, because the "mutations" of plants which are the basis of the inferences of Professor De Vries are not prepotent but "recessive," presumably because they do not represent true genetic variations, but are symptoms of what may be described as an evolutionary debility, due to inbreeding. The disappearance of mutative characters when the new variations are crossed with the parent form or with each other is merely the recovery, as it were, of the health of the species when the abnormal condition of inbreeding has been removed, as shown so conclusively in Darwin's well-known experiments with pigeons, and confirmed by an abundance of similar facts. Though differently interpreted, many other facts supporting this view were collected by Darwin, who summarized the results of his studies of Ipomea, Digitalis, Origanum, Viola, Bartonia, Canna, and the common cabbage and pea, as follows:

> The most important conclusion at which I have arrived is that the mere act of crossing by itself does no good. The good depends on the individuals which are crossed differing slightly in constitution, owing to their progenitors having been subjected during several generations to slightly different conditions, or to what we call in our ignorance "spontaneous variations." [b]

Differences between the plants of different habitats mean also different lines of descent and attendant variations, and the beneficial results of bringing these together may be explained by reference to symbasis rather than to the "slightly different conditions."

While it may not be insisted that species, as described and named by systematists, are never originated by "extraordinary births" or from "mutations," both suppositions are obviously improbable as general explanations. Mutations are seldom fitted to survive because they are less vigorous and less fertile than the parent type, so that they must be segregated at once in order to be preserved. And even prepotent variations have no necessary connection with the origination of species, since however rapidly the characters of a species might change, it would still be the same species until a subdivision had taken place. The more a species evolves the more different from its relatives it becomes, and the more satisfactory for the purposes of

[a] Mr. William R. Maxon, of the U. S. National Museum, calls my attention to a very early announcement of the mutation theory.

"The truth is that species, and perhaps genera also, are forming in organized beings by gradual deviations of shapes, forms, and organs, taking place in the lapse of time. There is a tendency to deviations and mutations through plants and animals by gradual steps at remote irregular periods." Rafinesque, 1832. Quoted in Journal of Botany, 30 : 310.

[b] Darwin, The Effects of Cross and Self Fertilization in the Vegetable Kingdom, p. 27. New York, 1895.

systematic study, but this progressive transformation of the "type" carries with it no necessity for subdivision, nor any indication that evolution is concerned with the origination of species.

SUMMARY.

Evolutionary study and thought have been hindered by the confusion of two unrelated biological phenomena, (1) evolutionary progress or vital motion, and (2) the origination or multiplication of species. The "origin" of a species is not more evolutionary than any other stage in its history. The causes of the subdivision of species are not causes of vital motion; the two processes are quite distinct. The separation of two species is not a focus of the evolutionary problem; it is a mere incident of developmental history.

Segregation is the principle or active cause of the multiplication of species, but the nature and causes of evolutionary progress are not to be ascertained by discovering that species originate by subdivision. Vital motion is continuous, and is neither actuated nor interrupted by the segregation which multiplies species.

Natural selection may assist in the segregation of species, but it is not a factor in evolutionary progress except as it influences the direction of vital motion. Specific groups become diverse when the component individuals no longer share their variations through symbasic interbreeding; not because new characters are induced by external influences. Evolutionary divergence may take place under identical conditions, and in characters which have no relation to the environment and no value to the organism except to permit the necessary vital motion.

A stationary heredity or the continued repetition of an identical structural type exists nowhere in nature; variation is an inherent evolutionary property. Segregation is not necessary for the preservation of variations; genetic variations are prepotent and are more rapidly propagated by crossing with the parent form.

A second evolutionary property of organisms is symbasis, which has built up the complex structure of the higher animals and plants by combining individuals into the interbreeding groups called species. The evolutionary species is not a complex of characters or a mere aggregation of similar plants or animals; it is a protoplasmic network held together by the interbreeding of the component individuals. Symbasis accelerates vital motion, but hinders the multiplication of species.

Species and evolution are different aspects of the same fact; evolution goes forward within specific lines as a manifestation of the same property which necessitates the existence of species; variation and cross-fertilization are not antagonistic phenomena, but are two phases of the same creative process.

SOME BIRD LIFE IN BRITISH PAPUA.[a]

By R. A. Vivian.

What British Papua lacks in big game it contrives to fill with fowls of the air, which, though varied and numerous, do not exist in that enormous quantity one would be led to expect of a fertile country lying only a few hundred miles south of the equator.

No classification of a technical nature, but a brief description of the different species and their habits, where known, being the object of this paper, further remarks will be unnecessary in introducing to the reader the typical birds of Papua, or New Guinea, viz, the birds of paradise, principally *Paradisea raggiana.* Our Teutonic neighbors evidently admire the birds so much that they have given them the premier position by striking local coinage on the obverse side with a somewhat exaggerated design of the greater bird of paradise (*P. apoda*).

The exquisite plumage of these birds having been already treated to a presumably microscopic survey, it is scarcely necessary to dwell further in that respect, but rather on their apparent desire to be noisy. Their rapidly ascending, shrill "caw, caw, caw," repeated, penetrating the ordinary stillness of the forest, being akin to a clarion call, while their prancing on a tree limb, which the natives introduce and imitate in their dances, is very ludicrous. Moulting seems to take place about August, which is near the end of the dry (or southwest) season. The noise of the rapids in large rivers and creeks appears to attract them, as they congregate there chiefly.

The writer is not aware whether it is widely known among ornithologists that a blue-plumaged bird of paradise exists in Papua.[b] Neither can he recollect meeting anyone who has seen the particular species in the flesh. The assumption is based on seeing tail feathers of the Opi tribe. The latter could not be induced to part with the

[a] Reprinted, by permission, from The Emu, Melbourne, October, 1904.

[b] I have seen in the national museum, Melbourne, a skin which is named *P. rudolphi.* (This species is recorded in Wallace's list of the Birds of Paradise published in The Malay Archipelago, 1890 edition. The habitat is there given as southeast Guinea.—Editors of The Emu.)

feathers of a sky-blue tint of a bird of paradise in the headdress of a chief for an ample consideration. Where and when they had been obtained the natives knew not, beyond pointing vaguely toward the mountains far inland. The local name, "damba," as for a *raggiana*, was also given.

The enormous goura pigeons (*Goura coronata*) are glorious creatures. The noble crests of mottled and slate-colored hues give the birds an almost commanding appearance. A peculiarity about these birds is that only in the River Musa district (latitude 9° to 10° south) are they to be found in considerable numbers. Whether a special kind of fruit tree only exists in the locality would be interesting to know, as otherwise that particular part of the mainland scarcely differs in any respect from other portions of the country east of longitude 148°. It is well known, of course, that a different variety of bird inhabits the Fly River districts (*G. d'albertis*).

Pigeons of lesser size, viz, the blue, white, black, and white Torres Strait, and the white necklaced varieties, mostly inhabit the mangrove trees on the coast in flocks, and toward sunset can be eaily shot, flying with alarmed cries in circles above their roosting place and returning in a few minutes within the zone of the sportsman's deadly gun fire. In the islands in the southeastern portion of the possession the beautiful blue-green bronze pigeon, with white tail and long neck feathers ("nicobar"), and a species with a remarkable fleshy protuberance at the base of the upper mandible, make their home in the thick scrub.

The varieties of doves are numerous, among which might be mentioned a very pretty particolored one with green, white, and yellow on its body and a patch of magenta above the beak, found on the Conflict Group. Also the almost tame green and brown species of the Lachlan Islands.

At all times of the day and night cassowaries can be heard uttering their peculiar plaintive cry as they wander through the dense forest. They are very hard to approach, and only on one occasion was the writer permitted to see a wild one, and that was through the effect of a lucky shot by a recruit in the armed constabulary. So far as it is remembered, the bird was of the common type peculiar to the country, and stood about 5 feet in height. A one-time planter in Milne Bay once kept a pair of these birds and trained them to perform the duties of watch dogs. As would be expected, black and also white (Triton) cockatoos (*Cacatua ducorpsi*); red, green, and blue parrots; rifle birds (*Craspedophora magnifica*), and scarlet-breasted green parrakeets are very numerous, and are to be found in flocks where cocoanut, breadfruit, banana, wild cherry, and plum trees are in bearing. Plait-billed hornbills (*Rhytidoceros undulatus*), in particular, devour these fruits greedily, and travel long distances from

their nests to satisfy their wants, making a start from home regularly at daybreak and returning at sunset. The male usually possesses a really fine head of golden feathers, which extend from the base of the bill quite 4 inches down the neck. The hen birds are all black, with the exception, as with the males, of a few white feathers on the under part of the wing. Corrugations to the number of 9 have been seen on the beak. What do these indicate? The rustling noise these birds make when on the wing is of a weird character, and, together with the hoarse note they produce, suggests to the imaginative the approach of something ill-omened. They fly in couples, at an estimated speed of 15 to 20 miles an hour in calm weather.

On a small island in the China Straits our boating party on one occasion disturbed a huge pelican (*Pelicanus conspicillatus*) that was evidently seeking food on the shore. Preparing to shoot it, we were discomfited by seeing it take a few bounds and with an apparent effort rise on the wing, and, lazily sweeping in gradually increasing circles, ascend until it was a mere speck in the sky.

The musical note of the magpie is heard occasionally in Papua. There is no mistaking its carol. The bird may possibly prove a new variety. Everywhere obi paradise crows (*Lycocorax obiensi*) in moderate numbers split the air with their hoarse cries and plunder banana plantations, and are especially fond of the paw-paw fruit.

Snipe (*Gallinago australis*) have been shot on the northeast coast, where in January they are found when migrating, though from whence, and whither bound, it is hard to say. Wild duck, too, are plentiful in the same locality. On the south coast and in the Gulf district small duck with a broad patch of white on the wing, and a variety about the size of teal have been obtained.

Vide extract of an expedition up the Morehead River, western division, several years ago:

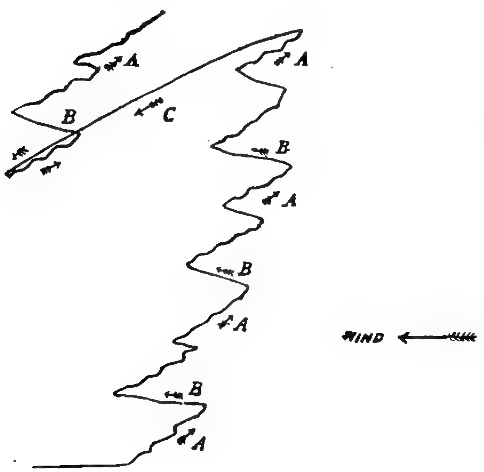
> There was a great variety of bird life, among which there were observed the white ibis and great heron, shags, enormous goshawks (*Erythrotriorchis doriæ*), wild geese and ducks, most beautiful long-tailed green and scarlet parrakeets, tiny jeweled kingfishers (*Ceyx solitaria*), and a little dark chocolate-colored velvety bird that lived in the reeds (probably *Megalurus alboscapulatus*), and quantities of pigeons, cockatoos, and parrots.

The black-feathered scrub hen, or brush turkey (*T. jobiensos*), is far from being a rowdy bird, and for its modesty in that respect rarely fills the sportsman's bag. A sudden splutter of wings and a dark object flying at a moderate rate toward where the scrub is thickest complete the disgust of the man with the gun. One receives some compensation, however, by being able to raid rather easily the ground nests of these birds for eggs. The nest, or rather natural incubator, is usually at the base of a large tree trunk, where the hen lays her eggs and then covers them over with a huge but light mound of dry

leaves 2 to 5 feet deep and quite 12 feet in diameter. The heat of this rubbish does the rest, and the young find no difficulty in scrambling out into daylight in due course. The egg is of a light pink color, and is about the size of a domesticated turkey's. Nests have been discovered at a height of 2,500 feet above sea level.

On a Government banana plantation, and on large streams, the writer often perceived hosts of swifts (*Collocalia terræfrancica*) appear an hour before sunset, darting rapidly hither and thither, as if feeding on minute insects of the air. This generally occurred during the wet season, November to February.

It was from the same point—Cape Nelson—that a coming "blow" from the southward was always heralded some hours before by the appearance of a few frigate birds (*Fregata aquila*), which hovered in the locality while the wind lasted, and as like mysteriously disappeared. It would be more appropriate to call them "prophet birds." During a gale they meet the fierce gusts with seeming equanimity, neither wing moving; but with bodies rigid and heads to windward they remain almost stationary, except occasionally a slightly perceptible swaying and momemtarily opening and closing of the tail feathers—a steadying agency probably, besides an aid of ascent—of which a few remarks will be added later. Then with a lightning turn they gracefully sweep at a downward angle with fearful velocity for any given distance with the wind, and then with the most consummate ease bring up "all standing," poised as before, the wings meantime remaining stiff, but scarcely horizontal, at the time the bird prepares to turn. Such a resistance do they offer to a storm that sometimes when a bird is balanced a short distance overhead one can almost imagine seeing the wind rushing past its form. They have never been seen to approach the water closer than 300 feet, while, on the other hand, they often soar upward to a considerable height. The evident method these birds adopt to ascend is peculiar, and very interesting to watch at close quarters. For, though the bird itself is practically rigid, except for slight movements—particular parts of which have been alluded to—yet those simple actions really explain how the bird rises. Thus,



in addition to what has already been stated, they consist of upward and downward motions, as if, while pressing against the wind, advantage is taken when a lull occurs (see Fig. A); and, secondly, with head still to windward, allowing itself to fall back a few yards as though for a "breather," but still maintaining a slight upward tendency during the progress (see Fig. B). Then repetitions ad lib. (See diagram.)

Their rate of speed when with the wind would be quite 60 to 70 miles an hour, if not more.

Mr. Louis Beck, writing in the Pall Mall Gazette, mentions the frigate bird as the swiftest of all sea birds, and in some of the equatorial isles of the Pacific it is used as a letter carrier. Taken from the nest before it can fly, it is hand fed on a fish diet by the natives, and in the course of a few months becomes so tame that it can be liberated during the day and will return to its perch at sunset. In the records of the London Missionary Society mention is made of the letter-carrying frigate birds of the Ellice group (northwest of Samoa), and that writer, who resided in those islands for three years, had frequent opportunities of witnessing their performances.

In the northern division the following birds have been recorded as existing there, and it would be interesting at a future date to learn of their respective peculiarities. They are the dollar bird (*Eurystomus*), New Guinea pheasant, weaver bird, and flycatcher (*Monachella muelleriana*). Brilliantly hued finches, wagtails, and racquet-tailed kingfishers (*Tanysiptera microrhyncha*) also excite curiosity. White-headed sea hawks (*Haliastur girrenera*) are not numerous, but are sufficient to make the owners of chickens very wrathful, owing to their depredations in the poultry run.

It may not, by the way, be out of place to devote a few lines to the native breed of domestic fowls. The male is a very pretty bird, very like a gamecock, with a long pendant on either side of the tail. A pure white variety is also bred, and is highly prized by the Papuans. Query: Where did these birds originally come from? All explanations are vague on the matter.

In the islands and several parts of the mainland curlews, golden plovers, and herons, both black and white, are free agents, and at as high an altitude as 6,000 feet on the main range the rare orange-crested bower bird (*Amblyornis subalaris*) has its playground.

Respecting the "death bird" of New Guinea, too much credence should not be indulged in until confirmed. Native myths are numerous and extraordinary, even precise in details. The moon, we are impressively told by some Papuans, was originally found in the soil by one of their number, who, in attempting to carry the luminary to his village barely escaped with his life through not relinquishing the prize as it ascended heavenward.

BIRD SANCTUARIES OF NEW ZEALAND.[a]

New Zealand has done two things thoroughly, as the following paper from The Argus of July 23, 1904, will show. One of these is to preserve those wingless birds so characteristic of the country, and which, because of their helplessness, would soon disappear as settlement increased; the other is to acclimatize the best game of other countries. Thus, in turning Canadian moose in their mountains, they brought a Canadian forester to look after the young calves, and a Scotch gamekeeper is now engaged in attending to the grouse. Resolution Island, in Dusky Sound, West Coast, discovered by Captain Cook, is named after one of the ships in which Cook made his first voyage. There is material for a charming little book on nature in this official document, the last place a Victorian, knowing something of the character of his own government reports, would look for it. And Mr. Henry's chat about the birds which are in his charge and have become, in some instances, his pets and friends, is so homely, so sympathetic, shows so much of close and loving observation, that something material to the literature of nature in New Zealand would have been lost had the notes not been published.

The wingless birds that are being given sanctuary on Resolution Island are the weka, or wood hen (*Ocydromus australis*), the kakapo, or great ground parrot (*Stringops habroptilus*), the roa (*Apteryx haasti*), and the kiwi, or apteryx (*Apteryx oweni*). In addition to these, which are his special charge, Mr. Henry writes of all the birds which are either native to or visit the island. It is the wingless ones, however, that are of chief interest. Had New Zealand possessed among its native fauna any destructive animals, such as the Australian dingo or the Tasmanian devil, these birds would have been extinct long ago. In settled country both dogs and cats play havoc with them, and the English weasel, which, as Mr. Henry observes, would never have been introduced had its habits been known thoroughly, is also destructive. When rabbits became such a nuisance that poisoned wheat was laid for them, some of the wingless birds were killed in thousands, like the English pheasants, which have been so successfully acclimatized. In many of the public reserves of

[a] Reprinted, by permission, from The Emu, Melbourne, October, 1904.

New Zealand, such as the charming gardens at New Plymouth, one can hear the pheasant calling constantly in the brush, and it is this thick native underwood which gave originally complete protection to the wingless birds.

The weka, or wood hen, is evidently one of the most interesting of the residents on Resolution Island. The quaint ways and quick sagacity of two of them, "Chicken" and "Scrag," who visit the caretaker's house on the lookout for table scraps, and share the contents of the dog's dish without risk, are amusingly described. These birds mate for life, and take turn about in hatching and protecting the brood. One of them is never absent from the nest from the time the first egg is laid until the young, which look like balls of soft down, are able to protect themselves. This care is the more necessary, as both the eggs and young are destroyed by rats, weasels, and sparrow hawks. Sometimes, of an evening, when the tide is low, the wood hens take their families out on the beaches, and the sparrow hawks watch for them there and kill the young by scores. The weka is, in its turn, destructive. Paradise ducks (*Casarca variegata*), like the wild ducks of Australia, cover up their eggs carefully with a mat of down when leaving the nest, but the wekas have an hereditary knowledge of the trick, and a young bird, which has never seen a duck's nest, tears away the down to get at the eggs the moment it discovers one. If they find a hen's nest with the eggs uncovered, they always go through the motions of tearing away the nest before starting to eat the eggs. Although on friendly terms with the caretaker, they hide their own nests away from him very carefully, and, if one of the pair comes to the house for scraps for its mate, it always takes a roundabout track to the nest, and is careful to see that it is neither watched nor followed. They kill each other's young, so that every pair on the island has its own run, and no others are allowed to intrude. Mr. Henry considers these birds most valuable as insect destroyers in an orchard, and observes that, if they were difficult to get, fruit growers would be quite keen about them. On the tableland above the Otira Gorge, when crossing from the west coast, one often sees the weka and her brood running along the track in front of the coach. When the first brood have been hatched and are fairly grown, the hen hands them over to her mate and starts to lay again. The male shepherds the young persistently, apparently gives them all the food he can find, and if they call for help in danger he is with them in an instant, keen for a fight. When he finds a rat he tackles it instantly, though not strong enough to kill it single handed. The squeaking of the rat is a signal to another weka, who rushes up and helps to kill the enemy.

It is surmised that the kakapo, or great ground parrot—the only parrot which does not fly—had once the use of its wings. Finding in

New Zealand no ground enemies and abundance of food and cover, it ceased to use its wings, which only subjected it to the risk of being taken by a hawk, and as the wings degenerated from disuse the legs developed in the same proportion, so that now it is a good runner. Tree parrots in Australia are awkard on the ground, but the seed-eating grass parrots all run quickly. In addition to the islands, which are so convenient a sanctuary, the government has two preserves for kakapos on the mainland. They are night feeders, though fruit eaters, an unusual combination, as Mr. Henry points out. Like the owls, they have a disk of prominent feathers about the eyes, and near the nose those long hair-like feathers or feelers common to nocturnal birds or those which have their home underground. They are so feeble, so unconscious of having enemies, that one may go up to them without their showing any alarm. If touched they are resentful, but if you sit down beside the bird a little while in daylight it tucks its head calmly under its wing and goes off to sleep again. Unlike the wega, the kakapo hides her nest away carefully from her own mate, who is generally both fat and indolent. These birds only breed every second year, and the curious point about them is that all the birds lay in the same season—a peculiarity which naturalists are quite unable to undertsand. Their call at night is very much like the booming of a bittern in the swamps, and the night drumming is only heard just before the nesting time. In the following year they are silent. The birds are always plentiful where wild berries grow thickly, and New Zealanders speak of such spots as "kakapo gardens." The young, when first hatched, are covered with snow-white down. The holes so frequently found in their gardens, where they have scratched, suggest that they dig for truffles, and it is known that they eat mushrooms.

The roa, another of the wingless birds, is distinguished by its wonderful beak—long, slender, and slightly curved. This, too, is a night bird, and rarely found far away from forests. It uses its long, snipe-like bill just for the same purpose that the snipe does its bill, except that it works in harder ground, and its chief food is earthworms. Its sight is poor, but nature, as is usually the case, compensates for this defect by sharpening up its sense of smell and hearing. When seen in the moonlight, it moves slowly along with its bill outstretched, and often stands with the point of its bill resting upon the earth, as though either trying to scent the worms or feel for their movements underground. The peculiar thing about their breeding habits is that a young bird a week or so old and a fresh egg are frequently found in the same nest. Like the wekas, the parent roas share the cares of a family, though in another way—the male does all the hatching. The young are born with all their feathers like mature birds, and apparently all their intelligence as well, for as soon as they

are hatched they start to search for their own food, and require no hints as to the best place to find it. The single egg, like that of the mutton bird, is exceptionally large. Thus, in the nesting season the hen, always in fine condition, weighs about 8 pounds, the "hatcher" 5 pounds and the eggs 18 ounces.

The gray kiwi is described as a shy, gentle, little thing, that seems to depend wholly for its existence on its ability to hide away in lonely places. They are shaped much like the roa, but have straight beaks. It is a light-loving bird, that feds by day mostly upon white grubs. It resembles the roa in its breeding habits, laying one large egg, hatched by the male bird, but while, in the nesting season, the pair of roas are rarely separated the kiwis are just as rarely found together. The young are very beautiful birds, quite silent, but so alert and cautious that if you take your eyes off them for a while they disappear. When grown, they have a shrill, whistling note, which Mr. Henry describes as like a guard's whistle in a railway train heard a little way off. In summer both the roa and the kiwi like to go up to the high ground, affecting naked mountain crests, and their pathways are clearly marked. The kiwi builds in a short burrow underground, generally protected at the mouth by the root of a tree. In the case of both the roa and kiwi, it looks as though the male bird hatched continuously for about thirty days. They go on the nest fat and plump, and by the time the young bird is hatched are feeble skeletons.

THE HOUSE SPARROW.

By Dr. J. O. Skinner, U. S. Army (Retired).

Mr. Thompson, a Canadian, referring, about twenty-two years ago, to the unwise introduction into the United States of this intolerable nuisance when its character and habits were so well known in England, made the following statement: "What wonder that the English farmer stared in blank amazement when first he heard of it, or that he failed to account for the action, except on the assumption that America had been visited by a wave of temporary insanity." We shall attempt to briefly give a few of the facts from which this inference was doubtless drawn.

The house sparrow (*Passer domesticus*), commonly called in America the "English" sparrow, has been known for ages as one of the worst of feathered pests. The name "English" sparrow is misleading, since it would indicate that it originated in England which is not really the case, for its history begins with that of man, and it is referred to by Aristotle and many other European writers on natural history who followed him; in fact, there is reason for believing that it was known to people of whom we have no written history. When writing was invented the sparrow was selected for the hieroglyphic symbolizing enemy, and proofs of its destructive habits have been cited by certain authors showing that it has been the enemy of mankind for more than five thousand years. This prolific little poacher, belonging to the granivorous family (*Fringillidae*), not only does much damage to grain, fruit, and other products of the soil, and disfigures all buildings used by it for nesting purposes, but it is so pugilistic that it drives away many insectivorous birds which are of great benefit to those engaged in agriculture or horticulture. More than any other wild bird, it is attached to human dwellings and is not known to thrive anywhere far away from the habitations or works of men, extending its range in new countries as settlements are formed and lands are cultivated.

It has already fully adapted itself to all continents and has been transported to some of the most distant islands in the Indian and Pacific oceans.

In the fall of 1850, Mr. Nicolas Pike, of Brooklyn, N. Y., brought over from Europe eight pairs of this bird and turned them loose the following spring. For some unaccountable reason, unless it be that they were the recipients of too much kindness, they did not thrive, and in 1852 a second and more successful effort was made. In 1854 and 1858 it was introduced at Portland, Me., and at Peacedale, R. I., and a few birds escaped at Boston.

During the next ten years it was imported direct from Europe to eight other cities, and in one case 1,000 birds were sent to Philadelphia in a single lot. By 1870 it had become established as far south as Columbia, S. C., Louisville, Ky., and Galveston, Tex.; as far west as St. Louis, Mo., and Davenport, Iowa, and so far north as Montreal, Canada, thus gaining a residence in 20 States, the District of Columbia, and 2 provinces of Canada, and the end of its migration was not yet. Between 1870 and 1880 it had extended its habitat over 15,000 square miles, and in 1873 Salt Lake City and San Francisco had been reached by this rapid colonizer. Even this extended area did not satisfy its migratory instincts, for during the next five years it established itself in more than 500,000 square miles of territory, and by 1886 35 States and 5 Territories, practically all of the country east of the Mississippi (except parts of 3 Southern States), as well as 8 Western States, had been invaded and occupied. Its range of habitation now covered, including nearly 150,000 square miles in Canada, over 1,000,000 square miles, and by 1898 only 3 States (Wyoming, Nevada, and Montana) and 3 Territories (New Mexico, Arizona, and Alaska) were free. It is presumed that by this time it has reached even those districts, and its occupancy of the entire United States is complete.

Besides the United States, New Zealand and Australia have been much damages by the "English" sparrow, it being regarded in certain Australian colonies as a nuisance almost equal to the rabbit. Although introduced by an acclimatization society on the North Island of New Zealand in 1866, it threatened, sixteen years later, to spread over the whole island, since it appeared in the most inaccessible places, contrary to its usual preference for cities and towns. This was no doubt due to overcrowding, the result of its rapid propagation. Having been carried to Victoria in 1865, it was not long before it discovered and occupied Queensland, New South Wales, South Australia, and Tasmania, although thus far it has been excluded from Western Australia by vigorous legal measures prohibiting its introduction. It will no doubt reach there in due time on its own transportation. It has already migrated to many other parts of the world and may be regarded as a veritable little cosmopolite. It is also present on Mauritius, in the Indian Ocean, and having reached Honolulu twenty years ago, it is fair to assume that if it has not already "prospected" our possessions in the Philip-

pine Islands, it will do so very soon. On the Atlantic side it is found in Bermuda, the Bahamas, and Cuba, and possibly Porto Rico, although its presence there has not yet been reported. Its conduct in Bermuda since it was sent there in 1874 has been just as objectionable as elsewhere, so that, after at first punishing with a prescribed fine anyone who attempted its destruction, the lawmakers themselves were obliged, ten years later, to change their code by placing a legal premium on its extermination. Although the area of the islands is less than 20 square miles, nearly $3,000 was expended in two years for this purpose with no appreciable effect, so numerous had become the progeny of this prolific profligate.

Although the house sparrow is now very generally distributed over Pennsylvania, it first appeared in the Cumberland Valley (Chambersburg) of that State about 1872, according to the observations of Mr. Davidson Greenawalt, and may have emigrated there from Shippensburg, where one pair was carried from Philadelphia about 1868.

It considers itself at home everywhere, apparently, and evidently comes to stay wherever found. There is no instance in ornithology where any other bird has multiplied so rapidly or covered such an extensive area in so short a time. This is not altogether surprising when it is remembered how much it has been assisted until recently, by persons unfamiliar with or indifferent to its character and habits.

Not only has it been transported intentionally from place to place, but has been pampered until the mistake was made too manifest to be longer ignored. The number of eggs in a set varies from four to seven, and one pair of birds usually raises four, sometimes five, and even six broods, according to some observers, in a year. It takes very little computation to determine what the results of this extraordinary fecundity would presumably be in a single decade. As it always prefers cities, towns, or villages—in fact, does not go to the country except at harvest times, until it is crowded out by overpopulation following its rapid propagation—it is further protected, by this choice of habitation, against the dangers and hardships by which the increase of many other birds is restricted. As a rule excessive reproduction of a species in the animal kingdom, with its consequent overcrowding, results in disease (epidemics or parasites) which prevent its unlimited multiplication. This is not the case with the house sparrow; it is one of the most vigorous of birds, notwithstanding its numerous progeny. It adapts itself wonderfully to diverse conditions, being able to endure the prolonged heat of tropical summer as well as to survive the protracted cold of a Canadian winter.

In view of the reputation and record of this bird wherever found, and the repeated warnings given to those who were about to import it, the continued interest in it and persistent effort to secure and suc-

cor it have been, indeed, difficult to understand, unless in the belief that it was done with the mistaken idea that it would destroy insect pests, particularly canker worms, in the parks of cities, and where it was originally introduced. This error was pointed out at the time, but was ignored; in fact, such a sparrow "boom" existed at one period in this country that parties so infatuated found it cheaper to import direct from Europe than from New York and other places at home. There were two classes who always seemed anxious to have the house sparrow in this country. One was the European part of our population, who, remembering the surroundings of the homes they had left, longed for its familiar chirp and suggestive cheerfulness; the other was that class of people who thought they were getting an insectivore, although they were informed by competent authority to the contrary. Now, there is an insectivorous bird called and known in England as the hedge sparrow, but which is no sparrow at all. It is the *Accentor modularis*, belonging to an entirely different family (*Sylviidæ*), the old-world warblers, is related to the thrushes, and, like all of its family, feeds on insects almost entirely, while the sparrow family proper are mainly granivorous, except in the spring and summer when raising their young, which they feed on insects and other soft food. It is reasonable to suppose that the importer of the house sparrow confused it in his mind with the hedge sparrow.

Sonnini, in the Dictionaire d'Histoire Naturelle, nearly a century ago, writes that sparrows lived "only in society with man, dividing with him his grain, his fruit, and his home; they attack the first fruit that ripens, the grain as it approaches maturity, and even that which has been stored in granaries." He also states that "82 grains of wheat were counted in the craw of a sparrow shot by the writer; and Rougier de la Bergerie, to whom we owe excellent memoirs on rural economy, estimates that the sparrows of France consume annually 10,000,000 bushels of wheat." Reports from France have been confirmed by those from other countries, and the character of the house sparrow has been discussed in France, Germany, and Great Britain for more than four centuries. The damage done by it to agriculture and horticulture has been immense, simply incalculable, for it has been inflicted directly and indirectly.

Besides the direct injury by it to grain crops (wheat, corn, oats, rye, barley, buckwheat, etc.), to fruits, garden seeds, vegetables, and to buds, blossoms, and foliage of trees and vines, is also that resulting indirectly from its molestation of other wild birds which are known to be decidedly beneficial to the garden and farm. Testimony has been secured showing that there are at least 70 kinds of these, including martins, swallows, wrens, and bluebirds, which are interfered with to the great loss of farmers and gardeners. It not only succeeds

in many instances in preventing many desirable birds from nesting, by occupying their premises and driving them away, but it even devours their eggs while they are absent finding and feeding on insects.

For fifteen years, say from 1855 to 1870, after its colonization in America, the protests against its introduction were confined to a few well-informed naturalists and to such naturalized persons as had observed its ravages elsewhere. Gradually, however, its advocates and defenders became less numerous. The evidence of the little criminal's guilt was irrefutable, as determined by competent witnesses in the form of innumerable dissections.

Many methods, legislative and otherwise, it is true, have been adopted and pursued in various places to exterminate it, but without success. Pennsylvania enacted the following law June 4, 1883:

SEC. 1. *Be it enacted, etc.*, That from and after the passage of this act it shall be lawful at any season of the year to kill or in any way destroy the small bird known as the English sparrow.

Many other States have done as much and more. Some towns and counties have offered bounties. One State (Michigan) paid at one time a bounty of 1 cent per head on English sparrows.

Shooting, poisoning, trapping, and nest destroying have been resorted to without any appreciable effect.

Probably the most promising method of checking its increase would be the systematic destruction of its nests and eggs during the breeding season. This has never been done on a large scale, although a few years ago the city of Boston undertook to clear the nests from Boston Common. About 4,000 nests and 1,000 eggs were destroyed, but after three weeks the work was stopped by order of the mayor.

The northern shrike is known to kill English sparrows, but since it occurs in the United States only in winter, and does not usually frequent cities or towns, its work as a sparrow destroyer would be problematical. The outlook for relief from this pest and nuisance is therefore serious and discouraging.

A letter received by the writer from the late Dr. Elliott Coues, one of the leading ornithologists of his day, relative to this matter, contains the following disheartening statement:

The multiplication of these early lots and of many later ones has given the invincible foreigner an assured foothold over most of the United States from which he will never be dislodged. The case is paralleled in Australia and New Zealand. I led the "sparrow war" for twenty years and only surrendered to the inevitable. You may do what you please, shoot or poison as many as you can, more will come to the funeral, and nothing you can do will make any appreciable difference. The case is hopeless.

Although generally considered a town bird it is well known also in the country. Many insectivorous birds are driven away or

seriously interfered with by it, and the writer has frequently seen the martin dispossessed, after a desperate resistance, of the premises provided for it by farmers, and ultimately driven away entirely by the sparrow, from its home and neighborhood.

Referring to the advent of the English sparrow, the Kansas City Journal quoted some time ago from the Topeka Journal as having "an account of the first English sparrows brought to Kansas. In 1864, F. W. Giles conceived the idea of importing some of these birds. He shipped in all 28 of them. They were confined in cages at his place in Topeka until all but 5 had died. At last the 5 were turned loose to take their chances of life or death, though Giles had no hope that they would live. They fooled him. They took up their home in the neighborhood. The following autumn there were 12 birds. The second season found 60, and the third summer about 3,000. Then they increased so fast that no account could be kept, and in the twenty-five years which followed they spread all over the West."

SOME TIBETAN ANIMALS.[a]

By R. Lydekker.

Naturalists are speculating whether the opening up of Tibet, which is practically sure to follow the present expedition to Lassa, will result in the discovery of any new animals of special interest. So far as the smaller mammals, such as mice, rats, squirrels, shrews, etc., are concerned, it can not be doubted that systematic collecting will be sure to yield a certain number of new forms. With regard to the larger mammals, the case is, however, different, and it would be unwise to expect that any strikingly new type is likely to turn up, although important information will doubtless be obtained in due course with regard to the mode of life and the nature of the habitat of several of the mammals already known to us. The reasons for taking this somewhat discouraging view as to the prospects of discovering new animals of large size in Tibet are as follows:

In the first place, although few Europeans have hitherto actually reached Lassa, the country has been traversed to the northward of that city from east to west—notably by Messrs. Bower and Thorold in 1892—by travelers who have done all in their power to collect specimens of the fauna; while many sportsmen, naturalists, and collectors have penetrated far into the interior from either the eastern or the western border. Moreover, the typical Tibetan fauna inhabiting the high plateaus above 14,000 feet is closely allied to, if not absolutely identical with, that of eastern Ladak, which lies within the limits of Kashmir territory, and has therefore for many years past been readily accessible to Europeans. On the other hand, the mammals of the somewhat lower and apparently more or less wooded districts forming the eastern portion of Tibet range into the northwestern provinces of

[a] Reprinted, by permission, from Knowledge and Illustrated Scientific News, London, September, 1904.

China, such as Shansi and Kansu, where they have of late years been collected by Mr. F. W. Styan, an English tea planter. Not that our information with regard to the mammals of eastern Tibet depends by any means solely on the collections made in Kansu and Shansi. On the contrary, the great French missionary explorer, Abbé David, succeeded many years ago in penetrating into the heart of the Moupin district of eastern Tibet, whence he brought back a number of mammals belonging to types previously unknown to science. Practically all that has resulted from subsequent exploration and collection is to prove the extension of the range of these peculiar types into western China, and to add to them a few species differing only in comparatively trivial features. The absence of any distinctly new types in this west Chinese fauna seems to point to the improbability of any striking novelty among the larger types of animal life remaining to be discovered in Tibet.

Of the strange animals first brought from eastern Tibet by Abbé David, and subsequently obtained by Mr. Styan in western China, by far the most remarkable is the creature now known to naturalists as the great panda (*Æluropus melanoleucus*), although at one time denominated the particolored bear (fig. 1). In appearance this animal is, indeed, strangely bear-like, although far inferior in bodily size to most members of the *Ursidæ;* the rudimentary tail, plantigrade feet, short ears, and broad head being all ursine features. Moreover, it is not a little remarkable that a species of true bear (*Ursus pruinosus*) inhabiting Tibet not infrequently presents a type of coloration approximating to that of the great panda, in which the legs and underparts, together with a band across the shoulders and a ring round each eye, are sooty black, while all the rest is pure white. On the other hand, when the face of the great panda is compared with that of the much smaller and long-tailed arboreal animal inhabiting the eastern Himalaya, and known as the true panda (*Ælurus fulgens*), a marked resemblance can be detected, and when careful comparison between the teeth and skeletons of the two animals is made, it becomes apparent that the great panda is much more nearly related to the long-tailed species than it is to the bears. In fact, these two animals appear to be the Old World representatives of the raccoons and coatis of America, and thus afford one more instance of the close affinity existing between the faunas of eastern Asia and North Amer-

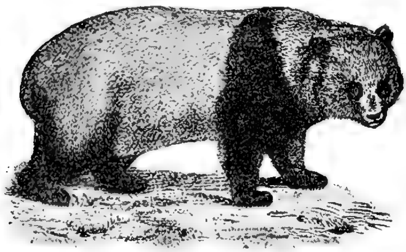


FIG. 1.—Great panda.

ica. The teeth of the great panda (fig. 2) are most beautiful and interesting objects—on the whole approaching much nearer to those of the lesser panda than to the ursine type. Of the habits of the great panda, we are at present in complete ignorance; but on this point we may hope in time to be enlightened by the opening up of Tibet. Whether we may ever expect to see such a wonderful creature alive in the Regents Park, it is difficult even to guess. Probably the great panda is a native of the more or less wooded districts of eastern Tibet, and not of the arid and elevated central plateau.

FIG. 2.—Teeth of right side of jaw of great panda.

The same must undoubtedly be the case with the Tibetan snub-nosed monkey (*Rhinopithecus roxellanæ*) (fig. 3), which was likewise the first-known representative of a new generic type discovered in the Moupin district of eastern Tibet by the Abbé David. It has, however, been subsequently obtained in Szechuan, while a second representative of the genus has been discovered in northwest China and a third in the mountains bordering the Mekong River. That the Tibetan representative of the snub-nosed monkeys, at all events, is a native of a cold climate may be inferred from its massive and "chubby" build and its thick coat, which in winter forms a long, silky mantle of great beauty on the back. As to the peculiar form of the nose, so utterly unlike that of ordinary monkeys, the suspicion arises that it may be in some way connected with life at a high altitude, seeing that the Chiru antelope, to be noticed later on, has gone in for a very strange development in the way of noses. At present, however, we are very much in the dark as to the relative height of the districts in which these strange monkeys are found.

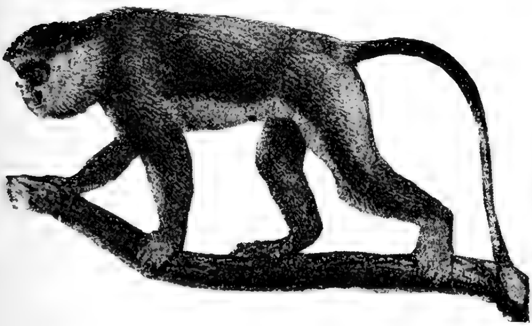


FIG. 3.—Orange snub-nosed monkey.

Nothing special need be said with regard to the above-mentioned Tibetan bear, except that it appears to be a peculiar species. The mere mention that the snow-leopard (*Felis uncia*) is an inhabitant of

the Tibet plateau must likewise suffice, seeing that this handsome cat has a wide range in central Asia.

Several species of deer are found in or near Tibet, although all of them appear to be confined to the wooded districts bordering the arid central plateau. The finest of these is undoubtedly the shou (*Cervus affinis*), a species allied to the red deer, inhabiting the forests somewhere near the head of the Chumbi Valley, in Sikhim. This deer is very rare in collections, where it is represented mainly by skulls and antlers, but it is probable that specimens will before long be forthcoming. A young individual is stated to have been killed during the early days of the Tibet expedition. Thorold's deer (*C. albirostris*) is a rather smaller and much darker colored species, readily distinguished by its white muzzle and the comparatively simple antlers. It exhibits the relatively heavy build characteristic of species inhabiting cold countries. This fine deer was first obtained in the wooded districts to the north of Lassa by the Russian explorer Przewalski, and subsequently by the English traveler Doctor Thorold, to whom the British Museum is indebted for its specimen. The third deer peculiar to the country is the Tibetan tufted deer (*Elaphodus cephalophus*), a species of the approximate size of a roebuck, and typifying a peculiar genus. In general character this deer is nearly related to the Indian and Malay muntjacs (*Cervulus*), the bucks being armed with similar long tusks in the upper jaw, but the antlers are even smaller than in the latter, being reduced to mere knobs, and there are distinctive peculiarities in the skull. This interesting deer was first obtained by the Abbé David in the Moupin district of eastern Tibet, but a second species was soon afterwards secured near Ningpo, in eastern China, while a third kind has recently been described from the mountains near Ichang, in central China.

In hollow-horned ruminants (oxen, sheep, antelopes, etc.) Tibet is specially rich, many of the species being peculiar to the country, where several of them are confined to the high central arid plateau.

The first place in this group must undoubtedly be assigned to the yak (*Bos grunniens*), one of the finest and largest of the wild oxen, specially characterized by the great growth of long, shaggy hair along the flanks and underparts of the body and the well-known bushy tail. In this country, unfortunately, a somewhat false impression of the yak is prevalent, owing to the fact that all the specimens hitherto imported belong either to a small domesticated breed from Darjiling or to half-breeds, the latter being generally black and white, instead of the uniform black distinctive of the pure-bred and wild animal. None of such half-breeds can compare with the magnificent half-tamed animals kept by the natives of the elevated Rupsu Plateau, to the south of the Indus, where they afford the only means of transport by this route between Ladak and India. And even these Rupsu

beasts are inferior to the wild yak, which stands nearly 6 feet at the shoulder. These magnificent animals are absolutely confined to the arid central plateau, on some parts of which, hitherto closed to Europeans, they are said to be comparatively numerous.

Another native of the same bare plateau is the Tibetan argali, or wild sheep (*Ovis ammon hodgsoni*), a magnificent animal, with horns of wonderfully massive proportions in the old rams. Since, however, this species is only a local variety of the true argali of central Asia generally, it is of less interest than the types exclusively confined to the country. The same may be said of the shapoo, or Tibetan urial (*Ovis vignei*), which is the typical race of a smaller race of wild sheep, whose range extends in one direction into northwestern India and in another into Persia. A third species of wild sheep, the bharal, or blue sheep (*Ovis nahura*), readily distinguished by its smooth and peculiarly curved horns and close gray-blue coat with black points, is, however, absolutely characteristic of the arid Tibetan plateau, on which it is found in large flocks. On the other hand, the Asiatic ibex (Capra *sibirica*), which frequents the more craggy ground instead of the rolling uplands, is a species with a very wide distribution in central Asia.

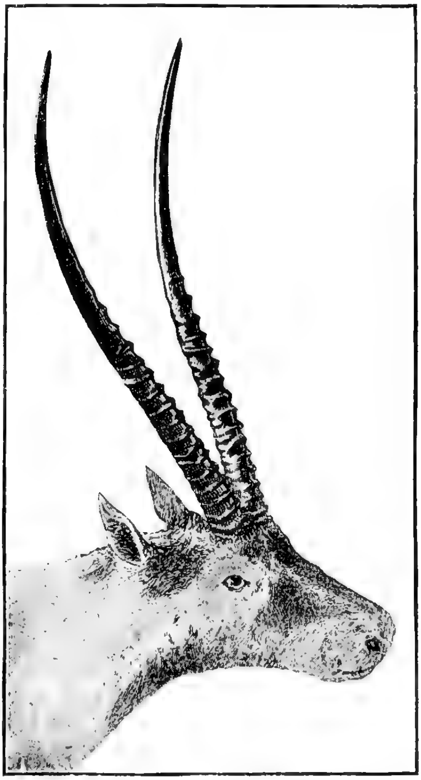


FIG. 4.—Head of male chiru.

Although the yak and the bharal may be regarded as repsenting by themselves distinct subgeneric types, all the hollow-horned ruminants hitherto mentioned are members of widely spread genera. We now come, however, to a remarkable species, which is the sole representative of a genus quite apart from any other and absolutely restricted to the arid central plateau. This is the graceful chiru, or Tibetan antelope (*Pantholops hogsoni*), of which the bucks are armed with long, slender, and heavily ridged horns of an altogether peculiar type (fig. 4), while the does are hornless. Possibly this handsome antelope may be the original of the mythical unicorn, a solitary buck, when seen in profile, looking exactly as if it had but a single

long straight horn. Although far from uncommon, chiru are very wary, and consequently difficult to approach. Like all Tibetan animals, they have a firm thick coat, formed in this instance of close woolly hair of a gray-fawn color. The most peculiar feature about the chiru is, however, its swollen puffy nose, which is probably connected with breathing a highly rarified atmosphere. This antelope has never been exhibited alive in a menagerie, and, as is the case with the other large mammals of the central desert plateau of Tibet, it would probably not live if removed from its native uplands to ordinary levels. A second antelope inhabiting the same country as the chiru is the goa (*Gazella picticaudata*), a member of the gazille group, characterized by the peculiar form of the horns of the bucks and certain features of coloration, whereby it is markedly distinguished from all its kindred save one or two other central Asiatic species.

The most remarkable of all the Tibetan hollow-horned ruminants is, however, the takin (*Budorcas taxicolor*), of which the typical representative inhabits the Mishmi Hills, in the southeast corner of the country, immediately north of the Assam Valley, while a second variety is found farther east in the Moupin district. The takin, which may be compared in size to a Kerry cow, is a clumsily built brute with yellowish-brown hair and curiously curved horns, which in some degree recall those of the South African white-tailed gnu. Its nearest relatives appear to be the serows of the outer Himalaya and the Malay countries, which are in many respects intermediate between goats and antelopes. As it lacks the thick woolly coat of the chiru and the goa, there can be little doubt that it inhabits a country with a less severe climate than that of the central Tibetan plateau, and it is probably a native of the more or less wooded districts of comparatively low elevation forming the outskirts of Tibet. It is one of the few large animals that hitherto appears never to have fallen to the rifle of a European.

With the large and handsome wild ass or wild horse (for it is, to a great extent, intermediate between the two), locally known as the kiang, we return once more to a characteristic denizen of the desert plateau forming the heart of Tibet. The kiang (*Equus hemionus kiang*) stands close on 13 hands at the shoulder, and is of a bright red bay in color, with the muzzle, underparts, and legs dazzling white. Its ears (fig. 5) are relatively much shorter and its hoofs much broader than in the true wild asses of Africa, from which it also differs markedly in color, while its cry is somewhat between a bray and a neigh. In the higher and more open parts of Ladak, kiang are to be seen in large numbers; and they come galloping round the convoy of the traveler in circles, with their heads carried high in the air, so that the face is almost horizontal. Whether the kiang is en-

titled to be ranked as a distinct species, or whether it should be regarded merely as a variety of the chigetai, or wild ass of Mongolia, and the lowlands of central Asia generally, is a moot point. But, be this as it may, the creature is absolutely confined to the central desert plateau of Tibet, where in winter it develops a coat as thick and rough as a door mat, in order to afford effectual protection against the rigors of that season at such an altitude.

In addition to the foregoing list of large mammals, Tibet is likewise the home of a number of peculiar species of smaller size. Among these it must, however, suffice to make mention of only two on the present occasion. Firstly, there is a remarkable species of water shrew, differing in many respects from the common water shrew (*Neomys fodiens*), and accordingly referred to a genus by itself under the name of *Nectogale elegans*. Of that genus it is the sole known representative. When we are fully acquainted with it the Tibetan palm civet (*Paradoxurus laniger*), at present known only by a single skin obtained so long ago as 1836, will prove almost as interesting a species, for it is quite probable that it will turn out to be generally distinct from the palm civets of India and the Malay countries, from which it differs by its woolly coat.

FIG. 5.—Head of kiang.

Such a large number of peculiar generic and specific types of mammals restricted to a continental area of the comparatively small size of the Tibetan plateau is a feature unparalleled elsewhere, and to find an analogous instance we must take the case of an island like Celebes, which has been isolated for ages from all surrounding lands. It would seem, therefore, that Tibet has been similarly isolated, so far as immigration and emigration of its animal fauna is concerned, for a vast period of time; an insulation due, doubtless, to its great elevation above the sea level, and the consequent severity of its climate and rarity of its atmosphere. Climatic peculiarities of this nature can only be endured by animals especially adapted to such conditions of existence, and it is accordingly only natural to expect that when once the Tibetan fauna had become modified for the needs of its environment it would have remained permanently isolated from that of the surrounding countries.

THE MULTIPLE ORIGIN OF HORSES AND PONIES.[a]

By Dr. J. Cossar Ewart, F. R. S.

Hitherto it has been generally assumed that wild horses have been long extinct, that all domestic horses are the descendants of a single wild species, and that, except in size, ponies in no essential points differ from horses.

Now that systematic attempts are being made to improve native breeds of horses in various parts of the world, it is obviously desirable to settle once for all whether, as is alleged, occidental as well as oriental and African races and breeds have sprung from the same wild progenitors, and more especially if all ponies are merely dwarf specimens of one or more of the recognized domestic breeds of horses.

To be in a position to arrive at a conclusion as to the origin of the various kinds of domestic horses, and at the same time find an answer to the important and oft-repeated question, What is a pony? one must clear up as far as possible the later chapters in the history of that section of the Equidæ to which the true horses belong.

It is generally admitted that the ancestors of the living Equidæ reached the Old World from the New, the later immigrants crossing by land bridges in the vicinity of Bering Straits. If horses came originally from the New World, to the New World we may turn for information as to their remote progenitors.

According to recent inquiries, North America possessed in pre-Glacial times at least nine perfectly distinct wild species of Equidæ. Some of these were of a considerable size—e. g., *Equus complicatus* of the southern and middle western States, and *E. occidentalus* of California were as large as a small cart horse. Others were intermediate in size—e. g., *E. fraternis* of the southeastern States; and at least one—*E. tau* of Mexico—was extremely small. Some of the American pre-Glacial Equidæ were characterized by very large heads and short, strong limbs, some by small heads and slender limbs, and although the majority conformed to the true horse type, two or three were constructed on the lines of asses and zebras.

[a] Abridged from Transactions Highland and Agricultural Society of Scotland, Vol. XVI, 1904. Reprinted, by permission, from Nature, London, April 21, 1904.

When true horses first made their appearance in America the climate and the land connections between the Old World and the New were very different from what they are to-day. One result of these differences was that before the close of the Pliocene period—i. e., prior to the great Ice age—it was possible for American horses to find their way into Asia and thence into Europe and Africa. One of the earlier immigrants (*Equus stenonis*) has left its remains in the Pliocene deposits of Britain, France, Switzerland, Italy, and the north of Africa. While *E. stenonis* was extending its range into Europe and Africa, two others (*E. sivalensis* and *E. namadicus*) were finding their way into India, and yet other species were doubtless settling in eastern Europe and central Asia.

It may hence be safely assumed that as Africa now contains several specie of zebras, Europe at the beginning of the Pleistocene period was inhabited by several species of horses.

We know that before the beginning of the historic age horses had become extinct in North America, but we have not yet ascertained what was the fate of the equine species which reached, or were evolved in, the Old World before or during the great Ice age. It is believed by some paleontologists that the Indian species, *E. sivalensis* and *E. namadicus*, became extinct, and that *E. stenonis* gave rise through one variety (*E. robustus*) to the modern domestic breeds, and by another (*E. ligeris*) to the Burchell group of zebras. *E. sivalensis*, unlike *E. stenonis*, but like the still earlier three-toed horse Hipparion and certain prehistoric South American species, was characterized by a depression in front of the orbit for a facial gland (probably similar to the scent gland of the stag), and usually by large first premolar (wolf) teeth in the upper jaw. In some recent horses having eastern blood in their veins there seems to be a vestige of the preorbital depression, and in some of the horses of southeastern Asia (e. g., Java and Sulu ponies), as in some zebras (e. g., Grévy's zebra and a zebra of the Burchell type found near Lake Baringo), there are large functional first premolars. It is hence possible that lineal but somewhat modified descendants of *E. sivalensis* of the Indian Pliocene may still survive, and that *E. sivalensis* was a lineal descendant of Hipparion.

We are, however, more concerned with the ancestors of the domestic horses of Europe and North Africa than with oriental horses.

From osseous remains already found we know horses were widely distributed over Europe during the Pleistocene period, and that they were especially abundant in the south of France in post-Glacial times. It has not yet, however, been determined how many species of horses inhabited Europe during and immediately after the Ice age, nor yet to which of the pre-Glacial species prehistoric horses were genetically related. Bones and teeth from deposits and caves in the south of

England seem to indicate that during the Pleistocene period several species of horses ranged over the west of Europe. The Pleistocene beds of Essex have yielded bones and teeth of a large-headed, heavily built horse, which probably sometimes measured more than 14 hands (56 inches) at the withers. From the "elephant bed" at Brighton portions of a slender-limbed horse have been recovered, and Kent's Cave, near Torquay, has yielded numerous fragments of two varieties or species which differed somewhat from the Essex and Brighton species. The "elephant-bed" horse has hitherto been described as very small, but if one is to judge by the bones in the British Museum it may very well have reached a height of 50 or even 52 inches (12½ or 13 hands). The Kent's Cave horses were probably from 13 to 14 hands high. One in its build approached the Essex horse, the other the slender-limbed species of the "elephant bed" at Brighton. If there were two or more species in Pleistocene times in the south of England (then part of the Continent), it is probable that yet other species inhabited south and middle Europe and the north of Africa.

As already mentioned, horses were extremely abundant in the south of France in the not very remote post-Glacial period.[a] Evidence of the existence of large herds we have at Solutré, where for a number of years there was an open-air Palæolithic encampment. Near the Solutré encampment (which lies in the vicinity of the Saône, about midway between Chalons and Lyon), the bones of horses[b] and other beasts of the chase were sufficiently abundant to form a sort of rampart around part of the settlement. It is difficult to say how many species of horses are represented at Solutré, but there seems no doubt that the majority belonged to a stout, long-headed, but short-limbed animal, measuring about 54 inches (13.2 hands) at the withers. Though of smaller size, the typical Solutré horse had nearly as large joints and hoofs as the Essex Pleistocene species. Like the Essex horse, it seems to have been specially adapted for living in low-lying, marshy ground in the vicinity of forests, and for feeding during part of the year on coarse grasses, shrubs, roots, and other hard substances, for the crushing of which large teeth, set in long powerful jaws, were indispensable.

That lightly built as well as stout species existed in post-Glacial as in Pleistocene times is made evident by bones found in caves and by drawings and sculptures made by Palæolithic hunters. Of the existence of two kinds of horses in post-Glacial times, practically identical with the stout and slender-limbed Pleistocene species, the cave of Reilhac, near Lyon, is especially eloquent. It is, however,

[a] An account of the prehistoric horses of Europe, by Dr. Robert Munro, will be found in the Archæological Journal, vol. lix, No. 234.

[b] Toussaint, of the Lyons Veterinary College, believes that at Solutré there were fragments of at least 100,000 horses, all of which had been used as food.

mainly by the engravings on the walls of caves in the Dordogne, Gard, and other districts in the south of France that the existence in late Palæolithic times of various kinds of light and heavy species of horses is made manifest.

FIG. 1.—Horse with a long head, from an engraving in the cave of La Mouthe. (Munro's "Prehistoric Horses.")

In the cave of La Mouthe, e. g., two horses are incised on the same panel—perhaps by the same hand—one of which (fig. 1) has a very long head attached nearly at right angles to a short, thick neck, while the other has a small head, Arab-like ears, and a long, slender neck, such as we are wont to associate with race horses.

In the Combarelles cave (Commune of Tayac), the walls of which for more than 100 yards are crowded with animal figures, there are, in addition to 23 nearly full-sized engravings of horses, numerous studies of equine heads. Some of the Combarelles horses decidedly differ from those of La Mouthe. There is, e. g., a large drawing of a heavily built horse (fig. 2) with a coarse head, an arched muzzle, a thick under lip, rounded quarters, and a tail with long hair up to the root. At another part of the cave there is what appears to be a natural-size engraving (fig. 3) of a head which in outline is wonderfully suggestive of an Arab, and at yet another part of the cave a horse with a pony-like head is represented, behind which stands an animal with a head like that of a modern Shire horse.

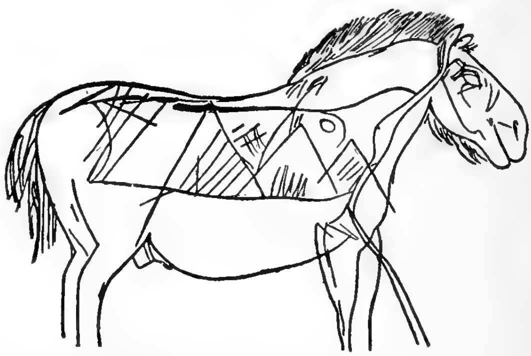


FIG. 2.—Engraving of a heavily built horse, from the Combarelles cave ($\frac{1}{18}$). (Munro's "Prehistoric Horses.")

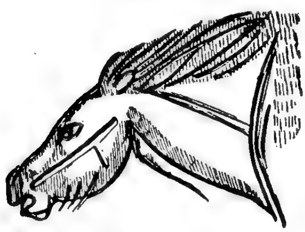


FIG. 3.—Head of a horse with a profile like that of an Arab, from the Combarelles cave ($\frac{1}{8}$). (Munro's "Prehistoric Horses.")

In addition to the types figured on the walls of caves, there are others carved on pieces of horn and other durable substances. The majority of the horses engraved on horn are characterized by a very large coarse head, but a few (e. g., the horse from the Kesserloch cave near Schaffhausen) are remarkable for the small size of the head, the fine muzzle, and small ears.

As already indicated, the men of the early stone age have left us drawings of some four or five different kinds of horses, some with large heads and stout limbs, some with fine heads and slender limbs, some with nearly straight croup and a well-set-on tail, others with rounded quarters and the root of the tail far below the level of the croup. Drawings made at the present day will be of little use some centuries hence in providing an answer to the question, How many species of horses existed in Europe at the beginning of the twentieth century? They will confuse rather than enlighten future inquirers, because for several generations breeders of horses, like breeders of cattle and dogs, have with the help of selection and isolation succeeded in creating numerous artificial strains. Is there any reason for supposing the evidence afforded by the prehistoric drawings is more valuable to us than recent drawings will be to our successors thousands of years hence, should they desire to ascertain how many species of horses Britons possessed at the end of the nineteenth century? That depends on whether in Palæolithic times the horse was domesticated in Europe.

It is extremely probable that the men of the early stone age had now and again tame horses, just as nowadays we have at times tame zebras, but it is most unlikely that they had herds of horses which they systematically bred and reared as stockmen now breed and rear cattle.

That the domestication of the horse as now understood was not attempted in Palæolithic times may be inferred from the fact that the majority of the horses in the Solutré bone mounds were from five to seven years old. Had horses been bred for food, as we nowadays breed cattle, young individuals would have been most abundant at Solutré.

If it is admitted that the engravings on the walls of caves and on pieces of horn fairly accurately represent animals which actually existed at the end of the ice age, and if it is also admitted that the creation of new varieties by artificial selection was never attempted until at the earliest the arrival of the Neoliths, it follows that in post-Glacial as in Pleistocene times there were several perfectly distinct wild species of horses in Europe.

For some reason or other it has hitherto been very commonly assumed that, as in recent times the wild striped horses of South Africa—the quagga and zebras—have been gradually supplanted by occidental or oriental domesticated horses, the wild horses of Europe were gradually displaced by domesticated varieties introduced by the Neoliths. It seems to me quite unnecessary to assume that the indigenous varieties so long familiar to the Palæolithic inhabitants were exterminated.

The advent of the Neoliths, instead of implying the extermination

of indigenous varities, in all probability meant the introduction of yet other varieties.

I may here repeat that now, as throughout the nineteenth century, it is generally assumed that all the domestic breeds—small as well as large—have sprung from a single wild species. The great French naturalist Cuvier believed not only that all living horses belonged to one species (the *Equus caballus* of Linnæus), but also that there was no specific difference between living breeds and the fossil horses of the Pleistocene period. Professor Sanson, of the French National College of Agriculture, in his Traité de Zootechnie (1901), assuming a single origin for domestic breeds, divides recent horses into two groups—a long-headed and a short-headed group—each of which consists of several races, while Captain Hayes, in his recently published Points of the Horse (1904), says, "no breed of horses possesses any distinctive characteristic which serves to distinguish it from other breeds," and adds that "as a rule locality * * * and artificial selection are the chief factors in the formation of breeds." Elsewhere Captain Hayes states: "As far as I can learn, no attempt has been made to separate ponies from horses except on the purely artificial basis of height."[a] Even those who are prepared to admit that recent horses may have sprung from several wild species allege that, owing to domestication, intercrossing, and artificial selection, it is no longer possible to indicate the distinguishing characters of the two or more wild species which took part in forming the present races and breeds.

THE WILD HORSE (*Equus caballus prjevalskii*).

The wild horse may be first considered. For many years the semiwild Tarpan of the Russian steppes was regarded as the nearest living relative of the wild ancestor of the domestic breeds, but in 1881 the existence of a true wild horse was announced by the Russian naturalist Polyakov. This horse occurs in the vicinity of the Gobi Desert and the Great Altai Mountains, one variety living to the southeast, another to the west, and a third to the south of Kobdo. All three varieties are of a yellow-dun color, the southeastern (Zagan-Nor) form being especially characterized by a dark muzzle, dark points, and a dark mane and tail; in the western (Urungu) variety the muzzle is nearly white, the limbs are light down to the fetlocks, and the mane and tail are of a reddish-brown tint, the southern (Altai) form being nearly intermediate in its coloration. The markings consist of a narrow dorsal band, faint indications of shoulder stripes, and indistinct bars in the region of the knees and hocks.

[a] Points of the Horse, pp. 422–425.

In all three varieties the mane is short and upright in the autumn, but long enough in spring to arch to one side of the neck; in summer the upper two-thirds of the dock of the tail carries short hair, the distal third long hair, which continues to grow until it reaches the ground; in winter the upper two-thirds of the tail carries hair from 2 to 4 inches in length. The hair of the body and limbs is short in summer, but under the jaw and over the greater part of the body and limbs it is from 3 to 4 inches in length in winter.

The hoofs are narrower and have longer "heels" than in the common horse, but, as in the common horse, each limb is provided with a chestnut and with an ergot, the hind chestnut (hock callosity) being very long and narrow.

In the variety (fig. 1, pl. I) occurring in the Altai south of Kobdo, probably the most primitive of the three, the head is large and coarse, and, compared with the length of the body, longer than in any domestic breed. In a side view it is noticed that the forehead is prominent (bumpy), the lower part of the face straight or slightly convex, the under lip long, and that the head forms nearly a right angle with the short neck. The eyes are lateral in position, and appear unusually close to the ears owing to the great length of the space between the eye and the nostril. The ears are long and generally project obliquely outward (fig. 1, pl. I), as in many cart horses. The croup is nearly level, but the hocks are usually bent and turned in. Judging by the behavior during the last two years of the wild horse in my possession, I am inclined to think his less remote ancestors, though in all probability members of the steppe fauna, lived for a time (perhaps during the Ice age) in the vicinity of forests. As is the case with other gregarious animals, he strongly objects to be separated from his companions, and he also objects to have his movements circumscribed by fences. It has often been said "nothing jumps better than a cart colt." The cart colt jumps because he has sprung from big-jointed, broad-hoofed, forest-haunting ancestors whose existence often depended on their being able at a bound to clear fallen trees and other obstacles. The wild horse when shut up in a loose box by himself is very restless, and keeps rearing up against the door until set at liberty; if placed in a paddock away from his special comrades he generally succeeds in either scrambling over or breaking down the fence.

The wild horse never encounters fences in the Gobi Desert, but, probably because he had forest-bred ancestors which had often to cross fallen trees, he endeavors without a moment's hesitation to clear all obstacles that come in his way, while true desert forms endeavor to break through them.

It has been suggested that the wild horse of the Gobi Desert is not a true wild animal, but only a domesticated breed that has re-

verted to the wild state.[a] Against this view I may mention (1) that all the wild horses are of a yellow-dun color, and that, though those to the west of Kobdo differ in tint from those to the east, the eastern and western varieties seem to be connected by the less specialized variety to the south of Kobdo; (2) that travelers in Central Asia all agree in stating that the Mongolian ponies vary greatly in color—in a Chinese hymn known as the "Emperor's Horses" as many as thirteen colors are referred to; (3) the descendants of the horses which escaped from the Spaniards in America after several centuries of freedom were of all sorts of colors; and (4) in horses which live in subarctic areas the hair at the root of the tail tends to increase so as to form a sort of tail lock, which when caked with snow protects the hind quarters during snowstorms; the complete absence of this tail lock—fairly well developed in one of my Mongolian ponies—is a very strong argument against the assumption that Prjevalsky's horse is nothing more than a domesticated breed that has reverted to the wild state.

The wild horse of the Gobi Desert is certainly the least specialized of all the horses living at the present day. In being of a yellow-dun color, in shedding annually the hair of the mane and the hair from the upper two-thirds of the tail, in having ergots and chestnuts on the hind as well as on the fore limbs, and in having canines and fairly large upper first premolars, Prjevalsky's horse is distinctly primeval. Only in the all but complete absence of stripes and in having very long powerful jaws armed with relatively large teeth can the Gobi horse be said to be specialized.

It is extremely probable that Prjevalsky's horse was familiar to the troglodytes who inhabited the Rhone Valley in prehistoric times. One might even go further and say that in fig. 1, from an engraving in the cave of La Mouthe, we have a fairly accurate representation of the head of Prjevalsky's horse.

It is, of course, impossible to say which of the recent breeds are most intimately related to the Gobi horse. Though the head and ears are suggestive of some of the heavier occidental breeds, in its trunk and limbs it more closely resembles Mongolian and Korean horses, some of which, like Prjevalsky's horse, decidedly differ from Shires and Clydesdales in having a small girth owing to a want of depth of body. To which domestic breeds the wild horse has contributed characters which will probably become more manifest after he has lived for some time under domestication. That heavy occidental breeds are not pure descendants of Prjevalsky's horse is sug-

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[a] It was formerly stated that the wild horse was simply a hybrid between a Mongolian pony and a kiang. I recently showed that a hybrid of this kind is quite different from the wild horse. See Proc. Roy. Soc. Edin., Vol. XXIV, part v, 1902–3, and Nature, Vol. LXVIII, p. 271.

FIG. 1.—PROFESSOR EWART'S YEARLING WILD HORSE IN SUMMER COAT.

From Hayes's "Points of the Horse." Photograph by M. H. Hayes.

FIG. 2.—CELTIC PONY, SHOWING TAIL-LOCK IN MIDWINTER.

Photograph by G. A. Ewart.

FIG. 1.—A TYPICAL CELTIC PONY IN WINTER COAT.

FIG. 2.—A RICHLY STRIPED DARK YELLOW-DUN HORSE OF THE NORSE TYPE.

Photographs by G. A. Ewart.

gested by the fact that cart horses, like zebras, have usually six lumbar vertebræ—the wild horse of Asia has only five, like the wild asses.

THE CELTIC PONY (*Equus caballus celticus*).

From the most primitive member of the Equidæ family I shall turn to the most specialized, viz, to what I have ventured to call the Celtic pony.

In color and markings a typical Celtic pony only differs from the intermediate (Altai) variety of the wild horse in having a slightly darker muzzle, a less distinct light ring around the eye, and a more distinct dorsal band. The hair is similar in structure, but slightly longer in the Celtic pony during winter (fig. 2, pl. I), more especially under the jaw—where it forms the so-called beard—over the hind quarters, and on the legs. In the mane, tail, and callosities the Celtic pony is very different from the wild Gobi horse. The mane is made up of a mesial portion (nearly twice the width of the entire mane in an Arab) consisting of strong dark hair, and of two lateral portions the hair of which is lighter and finer and less circular in section than the hair of the central portion. The mane in the adult grows at the rate of from 9 to 10 inches per annum, and as only about one-third of the hair is shed annually, the mane reaches a considerable length. Owing to the great width of the middle portion the one-half of the mane generally falls to the right side, the other to the left. The front part of the mane hangs down over the face to form a forelock (fig. 2, pl. I).

The most remarkable feature of the Celtic pony is the tail. To begin with, the dock is relatively very short—so short that one is apt to suppose it has been docked. The distal two-thirds of the dock carries long dark hairs, the majority of which continue to grow until they trail on the ground. During winter and spring the proximal third of the dock (about 4 inches) carries stiff hair from 3 to 6 inches in length, which forms what may be known as a caudal fringe or tail lock (fig. 2, pl. I and fig. 1, pl. II). In the case of Arabs and other semitropical horses, the first 1 or 2 inches of the dock are usually covered with short, fine hair like that over the hind quarters, but in the Celtic pony fine, wiry hairs from 4 to 5 inches in length extend right up to the root of the dock under cover of the body hair of the croup. The most distal hairs of the tail lock overlap, but are quite distinct from, the long persistent hairs carried by the lower two-thirds of the dock. The hair in the center of the fringe, of the same color as the dorsal band (fig. 1, pl. II), projects obliquely backward; the hair at the sides is light in color and projects obliquely outward. The presence of this very remarkable bunch of hair at the root of the tail was quite incomprehensible until I noticed what happened during a snow-

storm. The moment the storm set in the pony orientated herself so that the snow was driven against her hind quarters. In a few minutes the lock of hair was spread out to form a disk, to which the snow adhered, and thus provided a shield which effectually prevented the flakes finding their way around the root of the tail, where they would have soon melted and effectively chilled the thinly clad inner surface of the thighs. Provided with a caudal shield, long, thick hair over the hind quarters and back, and a thick mane covering both sides of the neck and protecting the small ears, a Celtic pony is practically snow proof. While the storm lasted the pony in question stood perfectly still, with her head somewhat lowered, save when she shifted her position as the wind veered from northwest to north. Very different was the behavior of an Arab and a thoroughbred Highland colt close by. After trying various attitudes the Arab, carrying her head low and to one side, made a rush for the shelter of an adjacent wood; the half-bred colt—prevented by her Celtic blood from running away—tried in vain one position after another, and long before the storm ceased looked thoroughly miserable and began to shiver as if chilled to the bone. It hence follows that the tail lock is not, as I at first assumed, an inheritance from a primitive ancestor akin to the wild horse, but a highly specialized structure which eminently adapts the Celtic pony for a subarctic environment. I need hardly say the caudal fringe is not a product of artifical selection, for even in Iceland, where it reaches its maximum development, neither its existence nor its use has, so far as I can gather, ever been referred to. It need only be added that to maintain a tail lock of this kind it is necessary that the short, wiry hairs of which it consists must be renewed once a year.

In separating asses and zebras from horses, stress has hitherto been laid on the difference in the mane and tail, and especially on the absence of hind chestnuts. As already pointed out, the wild horse during summer in its mane and tail agrees with asses and zebras. The mane and tail are hence no longer of specific importance. This is also true of the chestnuts, for in the Celtic pony, as in asses and zebras, the hind chestnuts (hock callosities) are completely absent. In the wild horse, as in the vast majority of heavy and cross-bred horses, the hind chestnuts reach a considerable size, but in asses and zebras and the Celtic pony I have failed to find any rudiments of hind chestnuts, either before or after birth. Further, in the Celtic pony the front chestnuts are small, and, still more remarkable, the fetlock callosities (ergots) have entirely vanished; in asses and zebras the ergots are always present, and in some cases still play the part of pads. The Celtic pony is hence not only more specialized—further removed from the primitive type—in its mane and tail, but also in having lost the fetlock pads (ergots) and the hock (heel) callosities. Nature makes little effort to get rid of use-

less vestiges, so long as they are harmless. When an ergot or a chestnut is accidentally torn off there is considerable loss of blood. It is conceivable that in the remote past horses which happened to be born without ergots proved better adapted for a life in the subarctic regions—were less likely to suffer from injury when moving through frozen snow and to become a prey to wolves—and hence had a better chance of surviving and leaving descendants.[a]

There is also evidence of specialization in the teeth of the Celtic pony. In many horses—e. g., the horses of southeastern Asia—the canines and upper first premolars (wolf teeth) are well developed, but in the Celtic pony the first premolars seem to be invariably absent, while the canines are either absent or very minute, even in old males. In all the typical Celtic ponies I have seen the head is small, Arab like in outline, and well put on to a relatively long neck; the muzzle is fine and slightly arched, the under lip short and well molded, the nostrils are wide, and the eyes on a level with the forehead, while the ears are short, white tipped, and carried as a rule in an upright position. Owing to the shortness of the jaws the proportion of the head to the body is as 1 to 2.50 instead of 1 to 2.20, as in the wild horse.

Except in size I have been unable to discover any difference between the skeleton and teeth of the Celtic pony and those of the small horse of the "elephant bed" of the Brighton Pleistocene. In the most northern part of Iceland, where the few pure specimens of the Celtic pony survive, only a height of 12 hands (48 inches) is reached. Under more favorable conditions the height would probably be 50 or 52 inches, the size of some of the "elephant bed" horses and of the smaller variety of the desert-bred Arab, to which the small, slender-limbed occidental pony closely approximates.

In temperament the Celtic pony is very different from the wild horse. Captain Hayes had no difficulty in handling the wild horse in my possession, but from first to last, though giving evidence of marked intelligence, it was absolutely irresponsive and spiritless. A Celtic pony, on the other hand, rapidly learns what the trainer wishes and responds with alacrity. In its keenness and speed, staying power and agility, a pure Celtic pony is as different from an ordinary heavy-headed Iceland pony (i. e., a dwarf horse) as an Arab is from a cart horse.

The question may now be asked, is my most typical Celtic pony a pure or nearly pure specimen of a once widely distributed wild species, or is it at most an approximation to an ideal type living

[a] If, as it seems likely, the absence of ergots (i. e., of spurs in the center of the footlocks) is an advantage in arid regions, such as the Libyan Plateau, we can understand their frequent absence in Barbs and Arabs.

representatives of which no longer exist? I regard the pony described above as an almost pure representative of a once widely distributed wild species, for the following reasons: (1) In its color and markings it is almost identical with Prjevalsky's horse, and not unlike some of the varieties of the wild Asiatic ass. (2) The hind chestnuts and all four ergots are completely absent. (3) The tail lock is perfectly adapted for its work—were the hairs shorter the fringe would be ineffective, were they longer the snow shield, if ever formed, would rapidly disintergate. (4) The first premolars are completely absent, and only one of the four canines is represented, and that only by a minute peg which barely projects beyond the gum. (5) The pony in question proved sterile with stallions belonging to five different breeds, as well as with a Burchell zebra and a kiang; but she at once bred when mated with a yellow-dun Connemara-Welsh pony, which closely approximates to the Celtic type. (6) Ponies having the more striking Celtic characteristics occur in isolated and outlying areas, where one would expect to find remnants of an ancient highly specialized species which perchance reached the Old World from the New in pre-Glacial times or during warm inter-Glacial periods—in, e. g., Iceland (which has been almost completely isolated since the twelfth or thirteenth century), the Faroe Islands, Shetland, the Hebrides, the west of Ireland, and Finland.

Flat-nosed variety of the Celtic pony.—In the Faroes, the Hebrides, and in Shetland there are slender-limbed ponies which, except in their color and the shape of the head, and in some cases the form of the hind quarters, closely agree with my typical Celtic pony. In these ponies the depression below the eyes is more pronounced, and extends well-nigh to the muzzle, which is nearly flat. The nostrils look downward, and the space between them, instead of being arched, as in the Iceland specimen, is flat, and forms nearly a right angle with the face.

Some of these flat-nosed ponies are of a foxy red color, others are dark brown. According to Landt, the majority of the Faroe ponies a century ago were foxy red—the St. Kilda ponies, 18 in all, seen by Martin at the end of the seventeenth century, were also of a red color—the others were with few exceptions dark. A foxy red Faroe pony in my possession has neither dorsal band nor bars on the leg, but it has a light mane and tail, a nearly straight croup, and well formed hind quarters. All the other foxy red Faroe ponies I have seen or heard of closely resemble the one in my collection.

The dark Faroe ponies, like the dark Barra ponies, only differ from the foxy red ponies in not having in every case a straight croup and a high set-on tail, while the dark variety of the Celtic pony found in Shetland is in build more like the typical Iceland specimens than the Faroe variety.

Herodotus (v. q.) says of the horses of the Sigynnæ—the only tribe he knew the name of across the Danube—they "are shaggy all over the body, to 5 fingers in depth of hair; they are small, flat-nosed, and unable to carry men; but when yoked to chariots they are very fleet, therefore the natives drive chariots." This description, so far as it goes, is singularly accurate of the foxy red Faroe ponies, even to their being very fleet "when yoked to chariots." It is extremely probable that in the red colored Faroe ponies we have a remnant of a very old and once widely distributed variety, the orign of which is never likely to be revealed. For some unaccountable reason the silver mane and tail are as a rule either handed on untarnished to cross-bred offspring or they reappear in the second or one of the subsequent generations. It is hence possible that various large breeds—such as the Suffolk Punch, the white-maned horses of the Hebrides and of the north and west of Ireland, certain silver-maned Hungarian and Russian races, not to mention Chittabob and other English thoroughbreds—have all inherited their light manes and tails from an ancient foxy red variety of the Celtic pony.

The origin of the dark-brown variety of the Celtic pony is also wrapped in mystery. These dark-brown ponies may represent another old variety from which the Exmoors have sprung—a variety which has contributed the tan-colored muzzle and the ring round the eye so characteristic of many of the best Highland and Island garrons. One of these dark-brown ponies, brought from Barra as a 2-year-old, looked for a time like a miniature thoroughbred. Now as a 3-year-old it might pass for one of the oldest and best type of the dark Færoe ponies. Neither the dark nor the red Faroe ponies ever possess all the Celtic characteristics; at the most they are three parts pure, and I may add they cross freely with Norwegian and other breeds, generally transmitting such Celtic "points" as they possess to their mixed offspring.[a] It is worthy of note that in some of the small-headed horses engraved in the Combarelles and other caves inhabited in Palæolithic times the croup is straight and the tail set on high, as in many Arabs; in others the tail, instead of being in a line with the croup, looks as if it had been an afterthought—an appendage inserted fairly well up in some cases, lower down in others, as is the case in many large and small horses with rounded quarters. In the engravings showing a small-headed horse with a straight croup we seem to have the foxy-red variety represented; in those with somewhat drooping quarters we may have a representation of the dark-brown variety of the Celtic pony.

If one may judge from its specialization and from its being now adapted for sub-Arctic conditions, the Celtic pony belongs to a

[a] See Marshall and Annandale, Proc. Cam. Phil. Soc., Vol. XII, Pt. IIV.

variety which at a very remote period branched off from the main stem and possibly reached Europe and north Africa long before the advent of the Neoliths, to become the progenitors not only of occidental, but also of African races.[a]

As might have been anticipated, Celtic characters can often be identified in British and other occidental breeds. Many thoroughbreds, which are an unequal blend of Barbs and of Arabs in which eastern races often prevail, and of light and heavy occidental varieties, show traces of Celtic ancestors. Many small thoroughbreds "ride like a pony," or have a pony head, or pony legs, some even want the ergots or hind chestnuts, or the tail has a vestige of a fringe, or there is the gait and temperament, alertness, and intelligence of the pony. Many of the Highland garrons have pony characteristics, and this is also true of all the old mountain and moorland breeds, more especially of the mealy-nosed Exmoor ponies and some of the better bred dun-colored Connemaras.

Even in Clydesdales of the older type pony characters sometimes surge to the surface, while in crossbred animals they sometimes predominate. Recently I heard of a powerful, active 17-hand horse, with a wonderful reputation for speed, strength, and staying power, in which the hind chestnuts, greatly to the surprise of the owner, were completely absent. On making inquiries as to the pedigree of this horse I ascertained he was bred in Caithness and was the grandson of a Highland pony.

THE NORSE HORSE (*Equus caballus typicus*).

During prehistoric times in certain parts of Europe a tundra fauna gave place to a steppe fauna, which later was succeeded by a forest fauna. Evidence of this succession we especially have in the rock shelter at Schweizersbild, near Schaffhausen. In the lower deposits the remains of the reindeer, musk ox, variable hare, Arctic fox, and other tundra forms occurred. Nearer the surface were relics of hamsters, the woolly rhinoceros, kiang, horse, and other denizens of the steppes; and on still higher layers the bones of the beaver, hare, and

[a] That the Celtic pony is akin to the smaller high-caste Arabs has already been hinted. The only fundamental difference, apart from the coat, main, and tail, between many small Arabs and a Celtic pony is in the ears; in the Arab they are long and often incurved at the points. The long ears of the Arab may either be due to eastern blood of the Kattiawar kind or to long ears being an advantage to the wild ancestors that frequented the great Libyan plateau, as long ears are of advantage to the mountain zebra and to the kangaroo of the Australian bush. About the origin of the large varieties of Arabs provided with ergots, with hind chestnuts like those of Prjevalsky's horse, a somewhat long head, a tendency to a Roman nose, large joints, and a circumference of 7½ to 8 inches below the knee, I am unable to offer an opinion.

squirrel, the badger, pine martin, and wild boar, the stag, roedeer, urus, horse, and other recognized members of a true forest fauna.

In the case of the Equidæ it is often extremely difficult to determine to which species any given bones belong, and hence it is impossible to state definitely that the horses found along with the hamsters and other steppe forms essentially differed from those which were contemporaries of the stag and wild boar and other typical forest forms.

It may, however, be assumed that even in post-Glacial times the majority of the inhabitants of the steppes would when mature be quite or nearly whole colored, while frequenters of the forests would as often be either striped or spotted; that, e. g., the horse which frequented the Rhine valley along with the kiang and woolly rhinoceros would resemble the wild horse (*E. c. prjevalskii*) which, with the kiang, now lives in the vicinity of the Great Altai Mountains, while the horse which at a subsequent period was a contemporary of the wild boar, stag, and roedeer would be more or less richly striped, and in its limbs and general conformation adapted for a life in or near forests.

That there is some ground for this assumption will, I think, be admitted when due consideration is given to results obtained by crossing various kinds of horses with a Burchell zebra. When ponies of the Celtic type—i. e., ponies which in their color are identical with Prjevalsky's horse, almost certainly the lineal descendant of the steppe horse of Palæolithic times—are crossed with a male Burchell zebra, hybrids are obtained which, while in build strongly suggesting a Burchell zebra, are as profusely striped as the great zebra of Somaliland, and have at least five times as many transverse stripes across the trunk as occur in their zebra sire. When, however, pony mares of the Norwegian type are crossed with a Burchell zebra the hybrids resemble in make their Norse dams, and in their markings closely approximate the common or mountain zebra. The explanation of these remarkable differences seems to be that in the case of the Celtic pony hybrids the remote (Grévy like) ancestors of the Burchell zebra control the development and determine the plan of the decoration, while in the case of the Norse pony hybrids the remote striped-horse ancestors contribute the more obvious characters—the Norse ponies having more influence in determining the plan of striping than the highly specialized Celtic ponies, from which stripes had probably all but completely disappeared countless generations before they began to fade on the horses which belonged to the forest fauna.

It is probable that the highly specialized Celtic pony, as well as the primitive Gobi wild horse, belong to the steppe fauna, and it is equally probable that the yellow-dun (Fjord) horse, in which a striped coat may be said to be latent, belongs to the forest fauna. If this be admitted, it follows that the environment of the Norse race has

been for untold ages so different from that of the Celtic pony and the wild horse that it centuries ago acquired the rank of a distinct species, or at least a well-marked natural variety.

The question now arises: Does there exist in any of the outlying parts of the world (where artificial selection has been made use of to conserve old rather than to create new types) horses of a red rather than of a yellow-dun color—more like the red deer than the kiang—horses with a sufficient number of imperfect stripes on the body and bars on the legs to indicate descent from ancestors decorated after the manner of the mountain zebra? As is now generally known, dun-colored horses with remnants of a striped coat now and again make their appearance in all parts of both the old and new worlds. It is also a matter of common knowledge that dark yellow-dun horses, sometimes with fragments of numerous stripes, are always to be met with in, among other places, Mongolia, Tibet, the northwest provinces of India (especially in the State of Kattiawar), and in the northwest of Europe, more especially in Norway, the Highlands and islands of Scotland, and in Iceland. With the exception of the Kattiawars, which, probably as the result of rigid selection, stand apart, all the others have many points in common—some of the dun Mongol ponies agreeing closely with Norwegians; but they all—the Kattiawars more than the rest—decidedly differ from *E. c. prjevalskii*, the wild horse of the Great Altai Mountains, and from typical specimens of the light yellow-dun Celtic pony.

The most richly striped horses I have hitherto come across occur in the northwest of Scotland. One of these recently examined is alike in make, color, and markings so unique, and looks so little modified by domestication and artificial selection, that it must, I think, be considered as a fairly typical specimen of a once wild species. The history of the yellow-dun striped race, to which the specimen alluded to belongs, has not yet been written, but there is little doubt that it was introduced into Scotland from Scandinavia about the end of the eleventh or beginning of the twelfth century. As this yellow-dun striped race may very well have been familiar to Linnæus, it may, I think, be taken as the type of the large occidental breeds, and known as the *Equus caballus typicus*. A typical specimen of the Norse variety is of a dark yellow-dun color, with black "points" and a nearly black mane and tail. The mane is long and heavy and tends to fall to both sides of the neck, as in the Celtic pony. Only a few hairs at the root of the tail are shed in summer, and there is no attempt to form a tail lock in winter, while the fetlocks, never very long, are limited to the region of the ergots. The forehead is decorated with narrow stripes, which in their number and arrangement agree more with the mountain than with the true Burchell zebra. A broad dorsal band extends along the back to lose

itself in the tail; there are stripes on the neck and faint stripes extend a short distance from the dorsal band across the body, as in the British Museum quagga, while the legs, especially in the region of the "knees" and hocks, are marked by distinct bars.

The ears are short and are carried in a nearly upright position; the forehead (which is not particularly wide), in having two ridges extending upward from the prominent eyes to meet under the forelock, differs greatly from the "bumpy" forehead of Prjevalsky's horse and the flat forehead of the Celtic pony. The space between the orbit and the nostril is relatively longer than in the Celtic pony, but shorter than in Prjevalsky's horse. The eyes project beyond the level of the forehead. In the Celtic pony the eyes are large and adapted for a wide range; in the wild horse they are some distance from the front of the head; in the Norse horse they are small and look downward rather than forward. The outline of the face becomes convex above the muzzle and ends in a somewhat long upper lip, adapted, like the upper lip in the giraffe, for feeding on leaves and twigs. In the neck and shoulders, trunk and limbs, the Norse variety may be said to resemble a small cart horse of the Suffolk type.

Compared with the wild horse, the withers are lower and the hind quarters more rounded, and the tail springs more abruptly and at a lower level, and hence fails to convey the impression that it is a direct continuation of the trunk. The dock is relatively longer than in the Celtic pony, but shorter than in the wild horse. The limbs are short, but the joints are large and the hoofs fairly broad; hence in a side view of the foreleg a considerable increase is noticed as the thick fetlock joint is reached.

It will be evident from what has been said that the Norse horse differs chiefly from the wild Gobi horse in being of a darker dun color, in being far more richly striped, in the shape of the head, size of the ears, position of the eyes, and also in the muzzle, mane, tail, hind quarters, joints, and hoofs. From the Celtic pony the Norse horse also differs in the color and markings; but it especially differs in the tail and in the greater proportional length of the distance between the eye and the nostril, and in having a complete set of ergots and chestnuts. It is inconceivable that the Norse variety could revert to the Prjevalsky horse type, or be regarded as an offshoot from the Celtic pony.

The question may now be asked, Is there any evidence that the Palæoliths of the south of Europe were familiar with horses of the Norse type? Figure 2, plate II, gives an imperfect idea of a specimen of the Norse race from the west of Ross-shire. If this figure of a horse still living is compared with figure 2, which faithfully reproduces an engraving made thousands of years ago in the Combarelles

cave by one of the artist hunters of the early stone age, it will, I think, be admitted the Norse horse probably belongs to a very ancient race.

I need only add that I regard the Norse race as the foundation of what in the Highlands are known as "garrons." Horses of this type may very well have been originally obtained by blending the old indigenous yellow-dun striped race with Flemish and French breeds imported direct from the Continent or introduced from England during the middle ages. Further, it is extremely probable that the Norse race took part in forming the small active Clydesdales of a former generation.

OTHER OCCIDENTAL HORSES.

In addition to Oriental and African varieties, which doubtless include several wild species amongst their ancestors, there are two or more Occidental varieties which in various ways differ from the Norse and Celtic races and from Prjevalsky's horse.

One of the latter races include long, low, heavily built animals with unusually long heads; another consists of short-bodied animals with a large head and a pronounced Roman nose.

The long-headed variety which occurs in the Hebrides and the Central Highlands reminds one of the horses engraved during the stone age on a piece of reindeer horn. In one specimen of this variety met with in Perthshire the profile is straight, and the distance from the orbit to the nostril is 13 inches, i. e., 2 inches more than in a member of the Norse breed of a like size, and 4 inches longer than in a 14-hands Connemara pony allied to the Celtic race. Some of these long-headed forms with a straight profile and a well-molded muzzle resemble the horses of the Parthenon.

Horses with a pronounced Roman nose also occur in the western islands and Highlands of Scotland, and in Ireland, Austria, America, and other parts of the world into which breeds were introduced from Spain. One of this Roman-nosed type, of a yellow-dun color, met with in the Outer Hebrides, was especially interesting. It very decidedly differed from members of the Norse race in the same district, but, on the other hand, it agreed in the outline of the head with some of the engravings in the Dordogne caves. It is hence conceivable that the Roman-nosed variety (from which the modern Shire breed may be an offshoot) is a very old one—a variety which was firmly established centuries before domesticated breeds first made their appearance in Europe.

SUMMARY.

I have endeavored to indicate that in post-Glacial as in pre-Glacial times there were several distinct species of horses, and that it is extremely probable some of the prehistoric species and varieties have persisted almost unaltered to the present day. I have shortly described three distinct kinds of living horses, viz, the wild horse of the Gobi Desert (*E. c. prejevalskii*); the Celtic pony, which, though no longer wild, may be known as the *E. c. celticus;* and the Norse horse, which may very well stand as the type of one of the large Occidental breeds, and be known as *E. c. typicus*. I have also pointed out that in addition to these three very distinct types—two at least of which have taken part in forming quite a number of our British breeds—we have a long-headed, heavily built variety with a straight profile, and a long-headed, heavily built variety with a more or less pronounced Roman nose. I have also indicated that in addition to several Occidental varieties there are several African and Oriental varieties, and I might have added that, in so far as the English thoroughbred is a mixture of African and Oriental varieties and of Occidental light and heavy varieties, it might be cited as an excellent example of a breed which includes amongst its ancestors several wild species—a breed which has had a multiple origin.

EGYPTIAN AND ARABIAN HORSES.[a]

By E. Prisse d'Avennes.

I.—Egyptian Horses.

Everyone knows that in spite of its admirable qualities the thoroughbred Arabian steed is rarely to be found on our stock farms. Although many people well qualified to speak have written at length upon the Arabian horses, there still remains a good deal to be said. But amidst the absorbing interest attached to the breeding and raising of this noble animal we should not allow ourselves to forget the Egyptian horse.

There has been much discussion as to the native land of the horse; but no one has yet been able to prove with any degree of certainty to what country we are indebted for this beautiful and useful quadruped. Some writers, influenced no doubt by the renown of the civilization of ancient Egypt and struck by the military scenes sculptured or painted on palaces—as at Thebes and Karnak—have advanced the theory that the horse had its origin in the valley of the Nile and was propagated throughout the Old World by the conquests of the Pharaohs.

This assertion, allowed to go unchallenged and almost without criticism, is refuted by every bit of evidence the Egyptian monuments can furnish.

The history of the Egyptian people divides itself into three great periods. The first is that of the primitive monarchy, from the founder Menes to the extinction of the kings of the twelfth dynasty, three thousand seven hundred and three years before the Christian era. This is the epoch of the invasion of the shepherds or hyksos.[b]

The dominion of the Asiatic conquerors over Egypt forms the second period. Their expulsion, about 1822 B. C., opened a new era of prosperity under the Pharaohs of the eighteenth dynasty and marks the beginning of the third period.

On the monuments of the first of these periods, such as the hypogea of Memphis, Beni-Hassen, Syout, and Koûm-el-Ahmar, the army is

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[a] Translated, by permission, from Cosmos, Paris, Apr. 2, 1904. Revised by the author.

[b] Hyksos signifies "shepherd kings;" "hyk" in the sacred language means king, and "sos" in the vulgar idiom stands for shepherd.

shown to be made up entirely of foot soldiers and no trace of any bas-relief or painting representing horses, cavalry, or war chariots is to be found on these monuments. This tends very strongly to make one believe that the horse was not known to the Egyptians before the close of the twelfth dynasty, after the campaigns of Osortassin in Asia. Without doubt it was with the invading shepherds that the horse first made its appearance and became naturalized in the valley of the Nile.

A searching study of these Pharonic palaces enables us to state positively that there is not a single representation of a horse on any of the Egyptian edifices erected before the invasion of the Hyksos. Only after the overthrow, and more generally after the expulsion of these Asiatic conquerors, do we find depicted on the Egyptian monuments military scenes in which horses and war chariots play a considerable part in determining the great changes in the tactics of the Egyptian army. Moreover, the ancient historians, like Herodotus, Diodorus Siculus, and Strabo, are unanimous in omitting any mention of the appearance of this noble animal prior to the epoch of the Hyksos invasion.

Had the horse been indigenous to the valley of the Nile the early Egyptians, who were accustomed to deify the more remarkable animals and plants of their country, would certainly not have neglected to give to one of their gods the head of the hardy and spirited courser who shared with man the dangers of the battlefield.

If they did not raise altars to him, as they did to so many sacred beasts, it is only because they held in abhorrence the people to whom the introduction of the beautiful animal was due.

Finally, if the first Egyptians did not institute sacrifices of horses, like the assouame' d' ha [a] of the Hindoos, it was because the flesh was tabooed on account of the inveterate hatred that the customs of the Hyksos had left among the earlier inhabitants of the land. Nevertheless, the Egyptians esteemed the horse too highly to employ him in agriculture, and never, except in one little bas-relief on the temple of Khons [b] at Karnak, do we find horses harnessed to a plow.

After the expulsion of the Hyksos, about two thousand two hundred years before the Christian era, the Egyptians began to give much attention to the equine race, and the care they lavished upon their breeding soon resulted in a great numerical increase.

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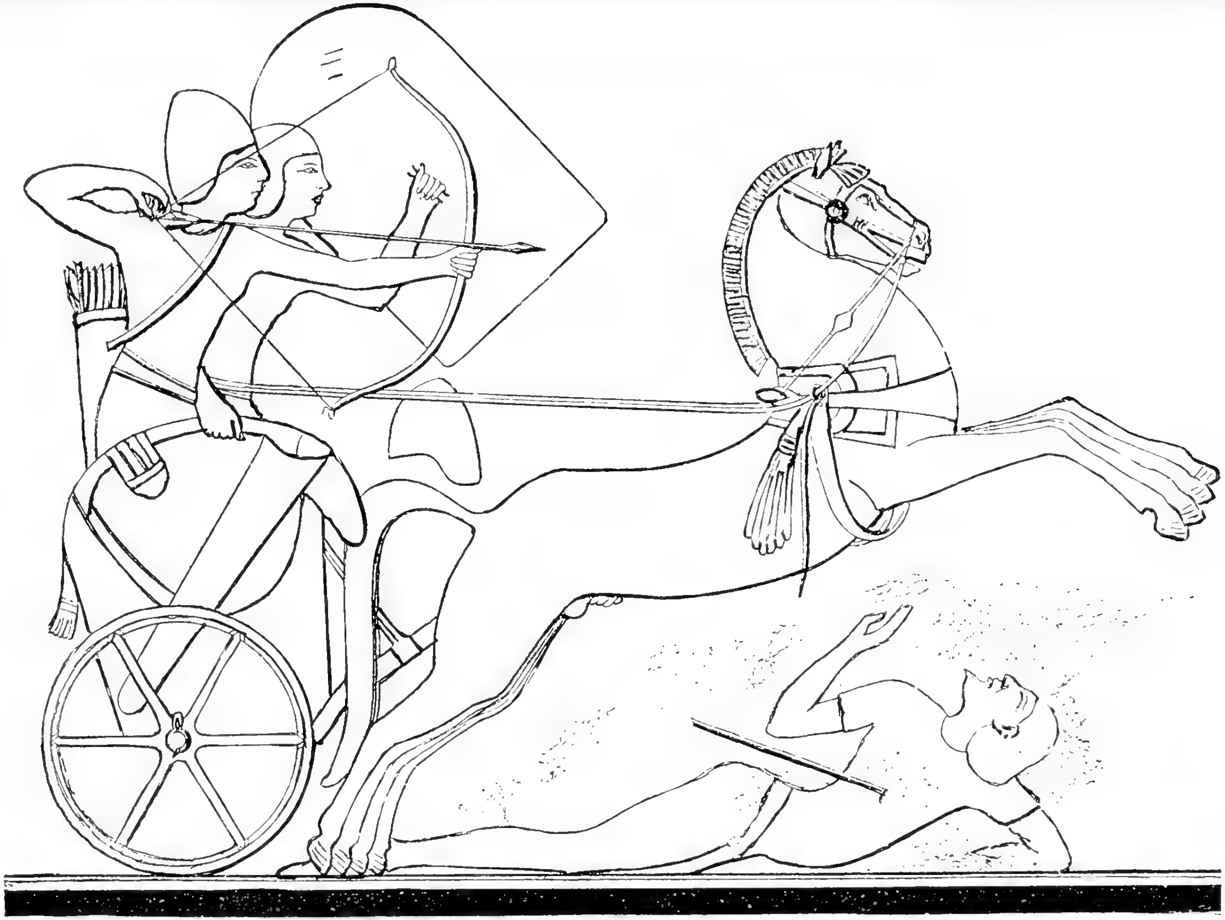
[a] The sacrifice of the horse, assouame' d' ha, is one of the oldest rites mentioned in the Hindoo books. It was considered very efficacious and always had a place in the honoring of the Hindoo trinity.

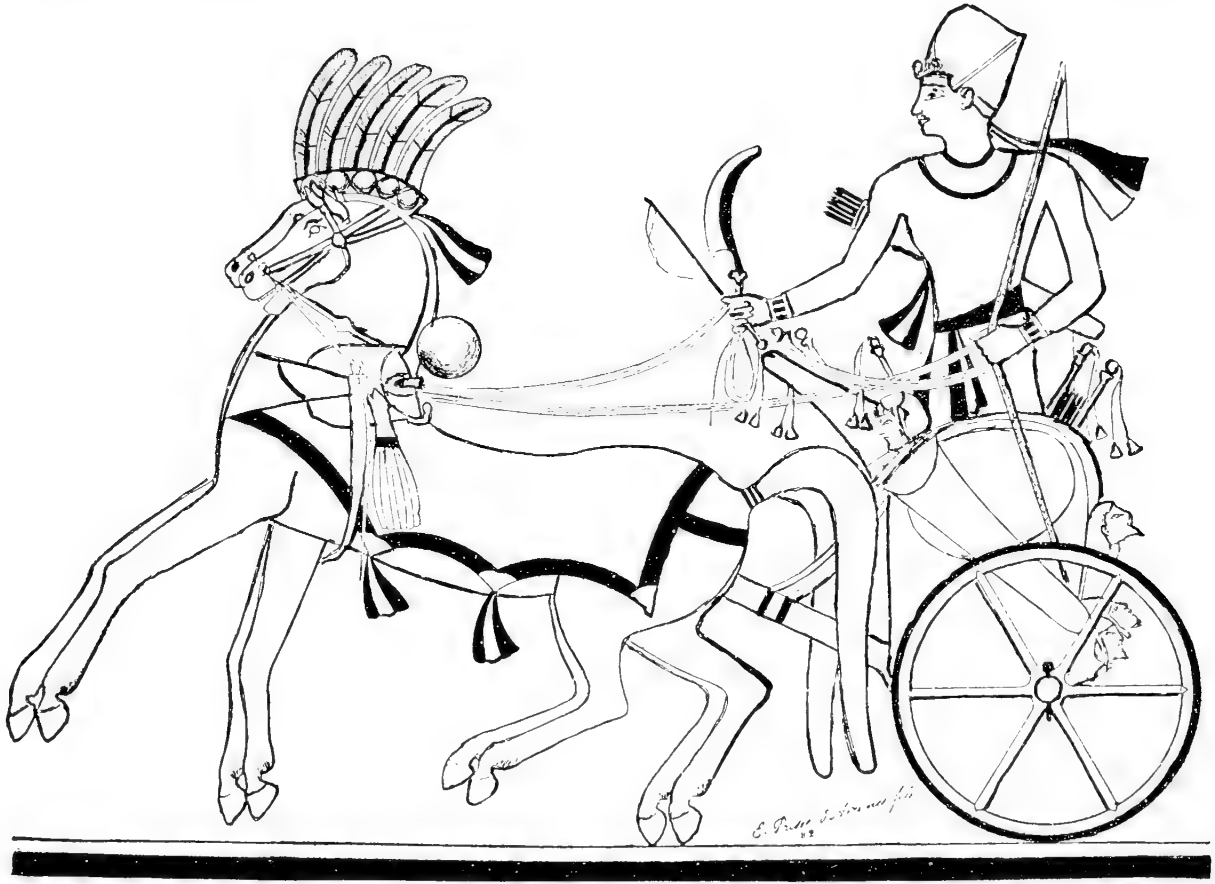
In some other sacrifices—known as the balidava—the Hindoos likewise offered horses, but instead of burning the flesh on the altar, they presented it raw to the gods.

[b] See, in any of the principal libraries, Monuments Egyptiens, by Prisse d'Avennes, large folio, Paris, 1847, pls. 35, figs. 2.



EGYPTIAN HORSES. BAS-RELIEF AT THEBES.

After Prisse d'Avennes.



EGYPTIAN HORSES. BAS-RELIEF AT TEMPLE OF KARNAK.

After Prisse d'Avennes.

It looks as though the ancient Egyptians early realized the beneficial effects of crossbreeding, for among the conquered peoples who paid tribute to Thoutmes III, of the XVIII dynasty, one thousand eight hundred and twenty-two years before the Christian era, came the envoys of an Adriatic race—probably Mesopotamia—who brought "horses," a chariot, etc. These imported animals were without doubt intended for the improvement of the Egyptian race.

Judging from the bas-reliefs and paintings, the Egyptian horses were tall, like the Nicæan horses of the plains of Media described by Herodotus. They had slender tapering necks, well-rounded chest and shoulders, high withers, long clean-cut legs, and long and plentiful tails. The colors in which they are generally represented on the monuments of the Nile Valley indicate that white, bright bay, and piebald were the common colorings. These are, in brief, the details furnished us by the Egyptian monuments of the time of the Pharaohs; the two accompanying figures give an exact idea of the curious old representations.

This vigorous species is still preserved in the upper valley of the Nile and is sometimes even found in Egypt where it is known as the Donkolawî; that is to say, a native of the province of Donkola in Nubia.[a]

These Donkolain horses, which do not, we are told, thrive in cold climates, are tall—5½ or 6 feet in height—black, bright bay, or piebald; the head is long and bushy, of the type common to the cows and sheep of this country; the face is quite attractive and intelligent, the shoulders well chiseled and round rather than square, the withers high, the flanks large, the chest, as a rule, full and muscular, the legs long and inclined to slimness, with white stockings on two or four feet.

The Donkolain is deliberate in starting and must be put into his paces gradually; then he has a brillant action, with movements agile, nervous, and elastic. He is very steady, can stand a great deal of fatigue, and shows much docility and affection for man.

However, the remarkable vigor which characterizes this horse in his native country is lost if he remains for any length of time in Lower Egypt. This degeneration, for which none can account, is so evident that the Egyptian Government, after the organization of its cavalry corps, was obliged to throw out of service all the Nubian horses in its ranks.

The crossing of the Donkolawî with Nedjedian mares, as tried at the Choubra stud near Cairo, produced very beautiful animals of very little value. This experiment, made probably without forethought, care, or sanitary precaution, could hardly be expected to give very

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[a] King Solomon supplied himself with horses from the rich studs of Egypt.

satisfactory results, and should not lead to the rejection of the Donkolain horse. Moreover, it is hardly to be expected that the best results can be achieved in the first generation, but rather by dint of continual interbreeding.

At present, as a matter of fact, the Egyptian horse is not a very distinct species; they have been bred so at random that they do not retain any of the characteristic forms or traits which would serve to distinguish them permanently.

The modern Egyptian horse is below the medium size, but is stocky and well filled out. His head is long, square, and ponderous, his large ears are as a rule awkwardly placed, his eyes are little but expressive, his nose is sloped off sharply and his nostrils flattened. He has a full chest between a pair of heavy shoulders, which are ordinarily square rather than rounded. His withers are not very prominent. The rump is deeply cleft, the stomach large, the hams and knees strong, the feet broad, the mane and tail coarse and abundant.

Not infrequently these horses have their front legs disproportionately short; their bodies are not always long enough for symmetry; and the head and hind quarters often resemble those of a mule. These faults, however, are traceable to the Syrian type, a breed which has contributed much to the composition of the modern Egyptian. Bright bay, chestnut, and a dirty gray are the colors usually found; white is not at all common, and, being the color of princes, is very much sought after; black is the rarest of all.

The Egyptian horse is gentle, docile, and generally quite lively. When excited his veins fill, his nostrils distend, his eyes shine; all his movements are full of fire and vigor, but his strength is soon exhausted.

The Egyptians show much consideration in the treatment of their steeds, but the way they raise, feed, and pamper them is not calculated to produce a remarkable breed. On account of this care the animals are too short winded to run any great distances.

The art of horse training is but comparatively little known among the Egyptians. A colt, within a few days after birth, is allowed to follow its mother on all excursions. The rider, however, is careful to stop often, so that the youngster shall not suffer for nourishment. Sick or well, the colt is weaned at the end of six or seven months, and then they give him very little food until he is 2 years old. Moreover, they take no pains about providing any transition from green food to dry. These habits have most deplorable consequences in underdeveloping and predisposing the animal to all kinds of sickness.

Like his predecessors in the days of the Pharaohs, the modern Egyptian does not use his horse for agriculture; he regards it as a

useful luxury and trains it with that idea only in mind. The pace and the gallop are the only gaits that the Egyptians ever teach their horses, and they have hardly any tricks of the horse trainer. They are generally broken in on a track or narrow place, where they can run at full gallop so close to a wall that they must turn on their hind legs as a pivot or, what is still more difficult, stop short on their front ones. This practice, however, is not without its injurious effects on the horses.

The ancient Egyptians did not shoe their steeds, which traveled everywhere without any detriment to their hoofs. Shoes were not at all necessary in Egypt and were not used except by the Turks, who introduced the custom in the cities and army. Unshod horses are not subject to foot diseases common among others.

As among the Arabs, signs, supposed to be lucky or otherwise, determine the value of a horse. Little knots formed by the skin at certain points are by far the most sought-for omens; next in importance come the stars on the forehead, then various other marks, and finally the shade of color. The inhabitants of Egypt, like those of Arabia and Turkey, esteem highly horses with three white feet.

All the luxuriousness of the Egyptian cavalier finds outlet in his horse's trappings, which are of a remarkable richness and beauty and greatly resembling those used in Europe during the middle ages. The saddles, equipped with high pommels, afford the rider a very secure seat. The saddle bow is well adapted to the configuration of both man and beast. In case of a fall the great stirrups aid in assuring safety, and they are of great assistance to a rider when using his weapons.

In order to correct various bad habits, such as biting, kicking, rearing, the Egyptian employs methods much more efficacious than the mere use of the sharp edges of his stirrups. When a horse bites they proceed to irritate him and then present him with a bad leg of mutton just from the fire. The pain that the animal experiences when he seizes this seething viand makes him think twice before biting again. The method of procedure with a rearing horse is equally simple. A groom or a horse trainer, carrying in each hand a bardaque or heavy water cooler full of cold water, accompanies his master. When the horse begins to rear the rider seizes one of the porous jugs and breaks it on the breast of his steed. The shock and the sensation of the cold water soon checks any tendencies of that kind.

At one time the Pasha Mohammed-Ali sought to improve his race of horses by establishing at Choubra a stock farm containing 450 mares from the finest herds of Nedjd and Syria. Under the supervision of a Frenchman this establishment was just beginning to meet with remarkable success when it was turned over to a Turkish director. In a very short time it met the fate of all European institu-

tions that have to struggle against the ignorance, prejudices, and laziness of the Turks or native Egyptians. The stud of Ibrâhim Pasha contained nearly 400 Nedjdian and Aneza horses; those of the Pashas Abbas and Kourchid were equally well filled with stallions and mares from Arabia and Haurân. Such a provision should certainly have assured Egypt a remarkable race; but so little was the method and care displayed in their administration and so great is the ignorance of the Egyptians and Turks of everything which pertains to the breeding and raising of horses that these establishments failed utterly to accomplish anything worthy of note.

As a result the breed of Egyptian horses, which in the past was famed for its virtues, is to-day nothing more than a mixture of all the races brought into that country since the Arabian conquest. These foreign elements have modified the shape and size of the Egyptian type to such an extent that the horse as we find him in no wise resembles his ancestors depicted on the bas-reliefs of ancient Egypt. However, it is a perfectly safe conclusion that none can compare with the thoroughbred Arabian—the only direct descendant of the pure-blooded horse.

II.—The Arabian Horse and His Principal Marks.[a]

The scarcity of the pure-blooded Arabian horse in our studs is a fact to be deplored, especially as this race must always be depended upon to ameliorate the breed of our horses. But their scarcity, as well as their value, will lend additional interest to a few details concerning the origin and the introduction into France of this valuable "regenerator."

The Arabian horse is par excellence the king of horses.[b] In every case where the blood is pure it presents the most perfect type, and in every case of mixture its offspring show some remarkable qualities. Almost alone it seems to have the faculty of improving the various breeds with which it is crossed and of perpetuating through successive generations its characteristic traits. As everyone knows, Arabian horses are wonderfully intelligent. Story after story is told of their extraordinary affection and sagacity. Moreover, they possess other admirable qualities. More than any other horse an Arabian can stand hunger, thirst, extreme fatigue, and bad weather. Consequently he makes an ideal war horse.

The Arabian horse was acclimated in France about the time of the first Crusades and is the foundation of our beautiful and powerful

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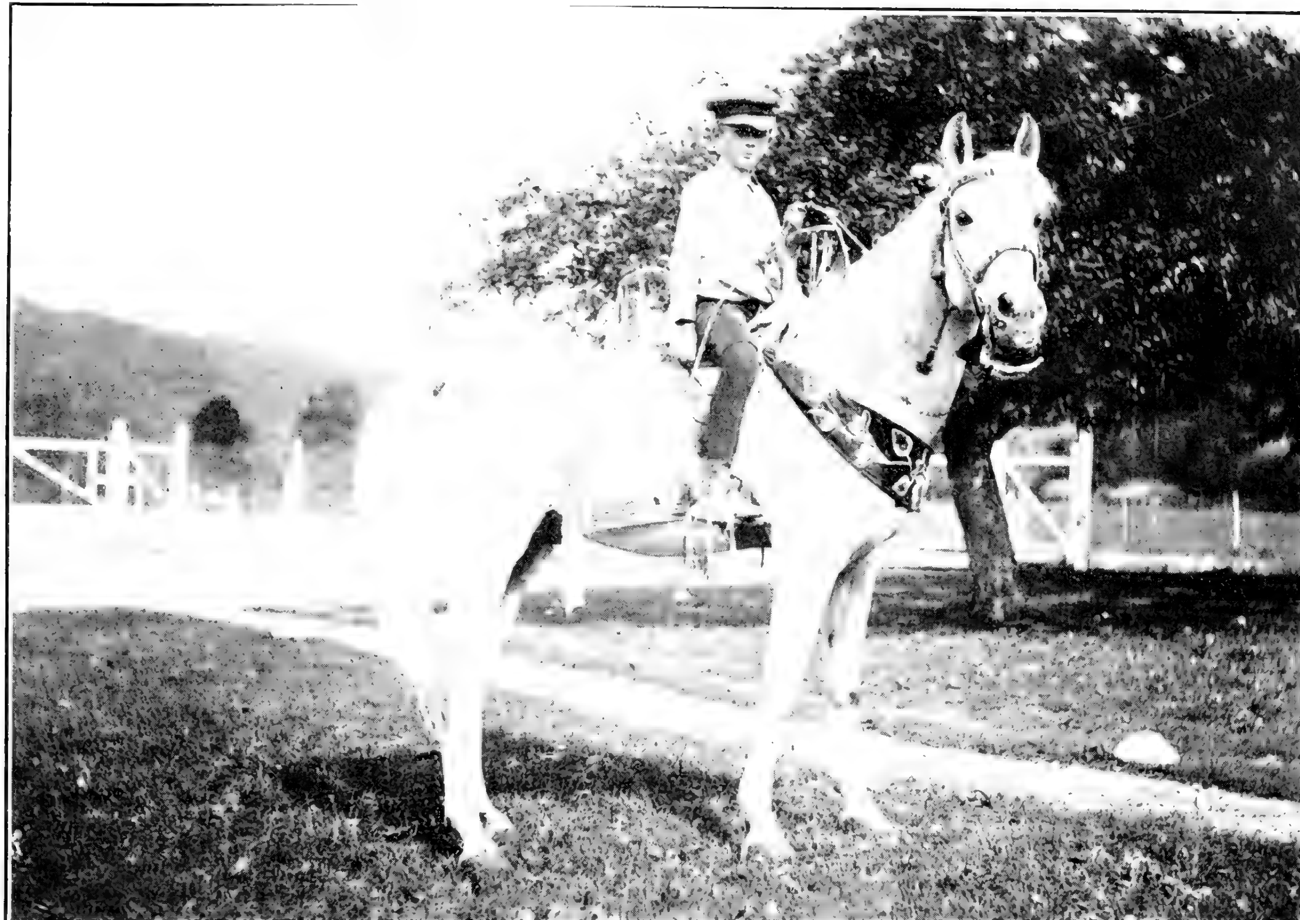
[a] Communicated by E. Prisse d'Avennes, 1905. Based upon an article originally published in "Science Française."

[b] Only the Persian horse can compare in beauty and mettle with the Arabian horse, for the Persians are as vigilant in guarding the purity of their breed as the Arabians.

ZEDAN. PURE-BLOODED ARABIAN COLT, PROPERTY OF THE DAVENPORT FARMS, MONTCLAIR, N. J.

Photograph taken at Davenport Farms.



OBEYRAN. IMPORTED ARABIAN STALLION, PROPERTY OF THE DAVENPORT FARMS, MONTCLAIR, N. J.

Photograph taken at Davenport Farms.

races of Limousin, Brittany, Ardennes, Auvergne, and others almost as well known.

The Romans valued most highly as a war mount the Numidian horse.[a] They used them with great success in their expeditions against the Germans, the Gauls, and the Scythians. During the Crusades the Frankish peoples brought home numbers of oriental horses, which they soon came to value highly for breeding no less than for war.

All the famous horses of history—that of Richard Cœur de Lion at Medina, of Philip Augustus at Bouvines, of William the Conqueror at Hastings, of Saint Louis at Massoure, of Francis the First at Pavia, of Henry the Second at the tournament in which he was killed, of Henry the Fourth at Arques de Ivry, of Louis XIV in his wars and fetes, and, finally, of Napoleon at Marengo and Austerlitz—all these horses were "Arabians" or "Barbs."

The Arabian horse is easily recognized by a peculiar physiognomy. He has always a remarkable expression which is not found in any other race and which seems to signalize him as the type of the species. His head is square and sharply chiseled; in front it is large and sometimes bulgy; the back of the skull is also well developed. The eyes are large, prominent, and ordinarily very beautiful, with the characteristic black lashes. The ears are small, well placed, and mobile. The lower jaw is a little strong; the forehead is hollow rather than prominent; the muzzle is sharp; the nostrils large and susceptible of great dilation when the horse is excited. The mouth is of medium size, with a small lower lip. A well-attached head and easy curve of neck and shoulder give an elegance to the animal. The neck is long enough to bend gracefully, and, when the horse runs, is thrown back to form what is termed the "stag neck." This conformation, looked upon somewhat as a fault, is natural to all animals who run long distances.

The withers of the Arabian are well filled out without being conspicuous; the back narrow, the sides rounded, the loins double and full, the hind quarters long and rounded. A well-placed tail is carried with vigor and grace. This horse, like all energetic creatures, is not above medium size. Its articulations are large and strong, its vigorous muscles show plainly beneath the skin. The rump, the withers, the hind quarters, are above all remarkable for their strength. The solid hocks are close together, a conformation peculiar to swift-running animals, like the stag and the gazelle.

The shoulder and foreleg are free and muscular. The delicate legs are clean cut, with detached tendons; the shank of the front leg is usually short and the saphenous veins inconspicuous. The feet are

[a] They must have existed long before the Romans were aware of their value, since Strabo placed at 100,000 the number of colts born each year in Numidia.

oval, with very hard black hoofs, the hind feet being sometimes a little rounded in the back. The mane and tail are not very full. The hide is delicate, the smooth and silky skin giving those splendid lights never found except on oriental horses.

Nedjed, in the center of Arabia, is the home of the first races of horse. The Arabs generally trace the origin of their breed of horses into the most remote days of paganism. There are two races or general divisions of Arabian horses; the Atik, that is to say, "pure" or "pure blood," born of Arabian father and mother; the Hedjin and the Moukrif, both mongrel or half-breed, the first having an Arabian father and a foreign mother, the second having an Arabian mother and a father of another race.

In Persia, in Syria, in Egypt, and the Magreb, although these countries themselves produce excellent horses, the Arabian courser is given the preference over all others, and the oriental warriors take great pride in owning them.

This much-vaunted animal does not conform with the generally accepted European standards of beauty in horseflesh, and many judges refuse to accord him a degree of perfection beyond reproach. Nevertheless, it is quite true that the Arabian steed surpasses all others in a magnificent combination of speed and strength.

When the blood is the same, the Arabs prefer very much a mare to a stallion for three reasons: The first consideration is the enormous profit to be derived from the former. Cases are known in which Arabs have made 10,000 or 20,000 douras ($10,000 to $20,000) on the offspring of one mare. There is a saying, "The fountain head of wealth, a mare which foals a mare." In the second place, a mare does not neigh in an ambuscade or night attack, and is less sensible than the stallion to hunger, thirst, and heat. Thirdly, in contrast to the stallion the mare requires but little care; she does not need much food and her master takes or sends her to pasture with the camels and sheep, without the expense of an attendant sais to prevent her from wandering off.

The Arabian horse has acclimated itself in every country where it has been introduced and stands undisputed the finest warhorse in the world. All climates are good to him, every latitude suits him, and he is satisfied with any kind of food. The ordeals which these horses underwent during the campaigns in Crimea and Russia are in themselves proof of this.

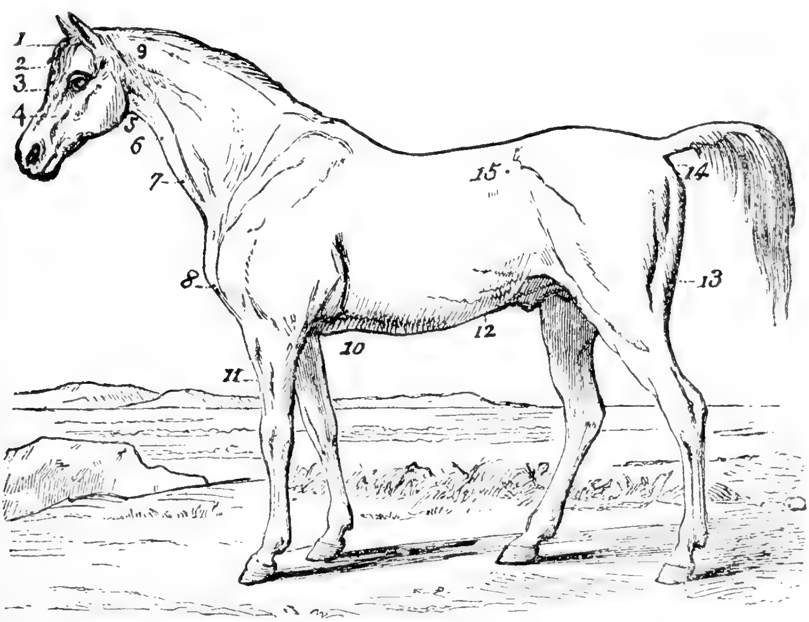
From the earliest times the Arabians have given studious attention to distinctive marks by which they may at first glance recognize the merits or defects of a horse.

The physical qualities prized mostly in their steeds are: A little head, pointed ears almost touching at their extremities, a large front face, eyes prominent and lively, lower jaw large but light, muzzle

tapered and bare, wide-open nostrils, a long, arched neck, strong chest, hind quarters high and rounded, belly inconspicuous, tail short and fine, nervous legs with short, flexible pasterns, and hard and ample hoofs. When the three principal qualities, that of head, hind quarters, and of legs, are found together the horse is considered perfect. But, on the other hand, when a horse shows any unlucky sign they will have him neither for mount nor for stallion. For there are several natural signs which the Arabs regard as significant, some as sinister for the owner or rider, others as favorable and luck bringing. Whatever superstitions they may show in similar matters it is certain that these ideas have had root in long-extended observations, and that superstitious as they are they would never consent to reduce by two-thirds the price of their horses bearing unlucky signs if there were not some mysterious foundation of truth in these beliefs.

The greater parts of these signs are small feathers, or epis, situated on different parts of the body. An "epi" is a little mesh or tuft of hair which makes a slight projection on a horse's hide. Each one of these has to the Arab a significance according to the place where it occurs and the length and fineness of the hair.

Here is a list of the most characteristic epis familiar in Mesopotamia, Syria, Nedjed, which is to say in the countries where the most beautiful horses of the Orient are found. The numbers refer to the figure—



Sketch of an Arabian horse showing the situation of principal epis.

1. Kanâdil: Two epis situated in the forelock near the temples; they are considered among the favorable signs.

2. El-cherikain: Two epis situated above the eyes; favorable sign.

3. Kabr ou Kabr maftouh, which translates "fall open;" An epi on lower front face, considered the most sinister of the signs and known to all Arabs.

4. Nadabat: Epis on both sides of lower jaw. Unlucky on a mare; without significance on stallion.

5. Ranakat: Epis on throat near the trough, considered favorable by some, unfavorable by others.

6. Hedjab: Favorable epis situated on both sides of the windpipe.

7. Chakk-el-djeib: Unlucky.

8. Nichan-el-sidr: Favorable.

9. El djeraid: Epi under the mane; favorable.

10. Nichan-el-cherihah: Favorable.

11. Nichan-el-dera: Insignificant when the white stocking does not reach it.

12. Nichan-el-sourrah or sabak: Epis on either side of the navel; favorable.

13. Boch-nichan: On the buttocks; unlucky; mares bearing this sign will have trouble in foaling.

14. Irmah: Unlucky sign.

15. Djennabat: Epis on the flanks. Without importance if covered by the saddle, but reputed unlucky if left uncovered.

An epi raised on the middle of the forehead like a solitary palm tree is a sign of great fortune and is called the "road to happiness."

The "hand of God," an epi on the upper front legs, prognosticates a victory for its rider, while a curling of the hair on the haunches indicates the reverse.

Horses which have epis on both sides of the tail are execrable; they are entirely bad when these funestral signs—probably identical with those called Irmah (14)—are not balanced by some other signs.

The omens which the Arabs draw from markings and other signs on their horses are not less remarkable than the qualities and faults they deduce from the epis. A black horse without any spot will bring misfortune. A black stripe on the back from the neck to the tail is an enviable sign. Black spots on the fetlock joint diminish by at least one-half the value of a stallion or colt. The horse with a hard cornea is not only swift, but very patient into the bargain, while a restive animal has, as a rule, small eyes and narrow nostrils. Horses with tawny hair around the pasterns are good for breeding.

"Look out," says the Arab, "for spots which are not exactly centered in the forehead.

"Any horse which has a white star and no white feet will carry you to destruction.

"Horses with black spots on the mouth are unlucky, wicked, and inclined to bite and kick.

"A horse with white on his lips and mouth will run faster than the wind.

"A horse whose white face stops on its nose will rear continually and throw the best of riders.

"If the upper lip is white underneath near the gums it is a favorable sign; if it is black it is unfavorable.

"A white mark on each side of the chest, back of the stirrup, indicates speed and safety; they are called 'the wings.'

"The horse with long white stockings is a dangerous brute. If the white runs higher on the right side than the left, sell him or prepare your burial garment.

"The horse with the chest of a lion, the hind quarters of a wolf, and the legs of a gazelle, long may he live."

These maxims show, if any such proof is needed, the great care the Arabs display in keeping pure the blood of their royal animal.

The preceding indicates sufficiently the superiority which the Arabian charger has had, and still has, over other races. It is hardly true—as many of our English trained horsemen insist—that the English horse is only the Arabian increased in stature and endowed with other qualities suited to the varied exigencies of civilization. With its growth in size, the English horse has lost its long wind, its courage, its sobriety, its endurance, and the suppleness of articulation; all of which are characteristic of the Oriental horse. The Arabian horse runs as well as the English, and if, as they say in England, the Arabian is perfected in that country, it is only by sacrificing all the solid qualities of the thoroughbred Arab to an exaggeration to a single one—speed—a quality which nature has not seen fit to give him as liberally as to more timid animals.

The horse, it has been said, is the expression of society; railroads, the automobiles, bicycles, telegraph and telephone, everything man has invented to devour space, though they tend to diminish the necessity for the horse, will never cause him to disappear. In spite of all our progress he will always remain an indispensable utility, and, if only for the use of the Army, we should endeavor to preserve the thoroughbred Arabian, the "regenerator" of all other races.

BEES AND FLOWERS.[a]

By E. L. Bouvier,

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That bees visit flowers is well known to everybody, as is the fact that these constant visits of theirs are by no means disinterested. Of the flower the bee asks two things: The pollen dust from the stamens and the sugared nectar, which most often is found at the bottom of the corolla. The pollen serves as food immediately, but among the social bees and very probably among the solitary species as well, the nectar must first undergo a series of changes. The cane sugar in this liquid, under the action of salivary products, is transformed into glucose. It acquires a peculiar taste and odor, and, as honey, is deposited by the bee in the cells of its hive, where it is mixed with pollen to form a nourishing paste, or consumed at once by its collector.

In their wild state adult bees live on honey and pollen exclusively; no other food will support them. Under domestication they will accept certain substitutes, meal in the place of pollen, and sugared water instead of nectar, but, when possible, they will invariably return to the flowers and feed as do their wild relations.

Among the solitary species, the female bee makes this paste of pollen and honey for her young; among the social bees, especially with our common honeybee, it is the sterile females or drones who attend to this duty. To speak more exactly I may say that the larvæ of the honeybee in their early stages are nourished with a peculiar jelly, rich in albuminoids secreted by the drone nurses, and that the larvæ of the queen bee subsist on this all through their evolution. Since this jelly is produced by the nurses out of the honey and pollen, I do not exaggerate when I say that these two substances are as necessary to young bees as to old.

[a] An abridged translation, by permission, from Revue générale des Sciences pures et appliqués, Paris, April 15, 1904.

I will soon describe the wonderful implements which the bees use in the collection of their food, but first let me show how sagacious they are in their visits to the flowers in search of it. According to the observations of Bonnier and de Layens, the assignment of honey bees to the various flowers varies considerably, but is always calculated. Every morning each swarm sends out its scouts to explore the neighborhood and to determine the proper plants and the places where they grow. On the return of the advance guard great numbers of workers go forth, some to collect pollen, others to pilfer for nectar. The principle of the division of labor is observed perfectly, each toiler collects one or other of the products exclusively, and almost always at the same trip, at least, limits his visits to a single kind of flower. Thus the work is done surely and rapidly.

"Bees and bumblebees," says Darwin, "are good botanists, for they know that varieties can show great differences in the color of their flowers without ceasing to belong to the same species. I have frequently seen drones fly straight from a plant of *Dictamnus fraxinella*, usually all red, to a white variety; from a variety of *Delphinium consolida* and of *Primula veris* to one of an entirely different color; from a dark purple *Viola tricolor* to a golden yellow one, and in two species of Papaver from one variety to another of a very different color. But in this last case, some bees flew impartially to one or the other species and acted as though the two were simple varieties."

Innumerable observations of this kind have been made. As Darwin indicates, the insects recognize at a distance the appearance of a desired flower, and, without doubt, its perfume as well. As a result of this instinct the honeybee adapts itself to circumstances and following the order of florescence, frequently changes its field of action. In the spring you find it visiting the few flowers then open, especially the catkins. A little later it frequents the cherry trees, the peach trees, and the pear trees; still later, when most of the corallas are radiant, the Leguminosae, especially the Robinia, the clover, and sainfoin, are favorites. Apiarists recognize this faculty of choice as an element to be considered in bee keeping, and often take advantage of it by cultivating not far from the hives plants which are covered with blossoms for a long time.

The processes employed by the bees for getting at the desired sweets are far from uniform. The honeybee, whose mandibles are not over strong, usually satisfies himself by crawling into the corolla, the Xylocopidae do not put themselves to so much trouble; one stroke of their powerful jaws lays bare the nectar. The mason bees and the bumble-bees often have recourse to the same rough method. Fre-

quently the ingenious honey bee takes advantage of the perforations made by earlier visitors of this class to get at the nectar more quickly.

But it is useless to dwell longer upon these points. Bees are admirably adapted to the collection of nectar and of pollen, and these two products are necessary to them and sufficient for them at any age, so much so that one may say, with M. Perez, that "every species of bee without exception would disappear if flowers should cease to bloom or if they should cease to produce nectar and pollen."

This fact well established—that flowers are indispensable to the bee, it is next necessary to see if the bees are in return of any service to the flowers, and, if so, how much. The question has been much discussed, and to this chiefly are due the differences of opinion that I will speak of in a few moments.

Before entering the thick of the fray, let me explain a few of the fundamental principles governing the fertilization of phanerogamous plants. In most of these plants, especially the more common ones, the stamens, or male organs, and the ovules, or female organs, are found in the same flower, which in that case is called a hermaphrodite. On its periphery are found the stamens crowned by the anthers containing the pollen and in the center rests one or more sacs which are united to form the pistil and which inclose a varying number—always infinitely less than the number of pollen grain—of ovules. For these to become seeds it is necessary that the pollen germinate on the pistil and, by working through it, unite with each ovule. In the plants of which the flowers are unisexual—that is to say, some flowers are male, others female—the process is the same except that in this case it is necessary that the pollen be brought to the pistil of the female flower.

This is brought about in two ways, by close fertilization and by cross fertilization. In the former the ovules are impregnated by the pollen of the flower which contains them, in the latter the fertilization is from pollen of a different plant. Darwin has shown that cross fertilization is much more advantageous to a plant than close, and that the maximum benefit is obtained in the crossing of two varieties of the same species. The advantage is shown in general by a more robust vegetation, an earlier flowering, and the formation of more and better seeds. Darwin's demonstrations rest upon an abundance of experiment and observation, and are, moreover, justified by modern practice extended even into the animal kingdom.

Nothing indicates more clearly the advantages of cross fertilization than does its great predominance in the vegetable kingdom; it is absolutely necessary in the case of plants with unisexual flowers, and, despite all appearances to the contrary, obtains in many, if not

most, cases of plants with the bisexual flowers. For there is that curious fact developed by Darwin and by many botanists, that when pollen of the same flower and pollen from another flower of the same species are placed simultaneously on the pistil of an hermaphrodite flower the latter will germinate more rapidly and will in most cases determine the fertilization. Clearly this must render crossing almost inevitable. Although the pollen of an hermaphrodite may fall directly on the contiguous pistil it is more than likely that a puff of wind or the visit of an insect will place on the same stigma some grains of foreign pollen in time to anticipate it.

But returning to the bees. We have shown the predominance of cross fertilization among the flowering plants and pointed out the advantages resulting to the plant. Now, if it can be demonstrated that the bees are the most active agents in this cross fertilization there will be no longer any doubt as to their usefulness.

All flowers, whether their reproductive organs mature simultaneously or at different times, give up their pollen to insects or to the wind or in a very great majority of cases to both. Plants whose fertilization depends entirely upon the action of the wind are called anemophiles. Lacking insect allies, all the primitive Phanerogams were anemophile exclusively, and have transmitted that characteristic to their descendants; they are represented by the Gymnosperms with unisexual flowers, of which the conifers are our best known type. Since the wind is an absolutely blind instrument so much of the pollen is lost that these anemophiles must produce considerable quantities. Walk through the woods at Vincennes a few weeks hence, and if the wind be right you will find the ground tinged with yellow by the pollen of the massive pines.

However, plants exclusively anemophile are few; the greater part of the flowering plants disseminate their pollen both by the wind and by insects. These two agents of distribution are by no means equally efficient; the wind blows the pollen dust about at random, while the insects carry it direct to the pistils of the flowers they frequent.

Darwin and numerous others found by experiment that at least half of the plants we grow are rendered entirely or partially sterile by being covered with a gauze to keep away the insects.

Generally speaking, the plants which require most insistently the visit of insects are those whose flowers are the most irregularly formed. Many of them have their flowers so arranged that the insect is forced in his attempts to reach the nectar to cover himself with pollen and thus produce cross fertilization. In no case is this more striking than in that of the sages; in these abnormal Labiates two stamens have disappeared and the other two have dwindled to a long connective loaded with a pollen sac. Entering the throat of the flower

to reach the nectar (at *ng*, fig. 1) the bee (D) strikes with his head the short sterile arm (*ac*) which acts as a sort of lever to bring down the long arm with its pollen sac (*a*) to cover his back with the fertile dust. Thus laden the busy workman flies to another flower and,

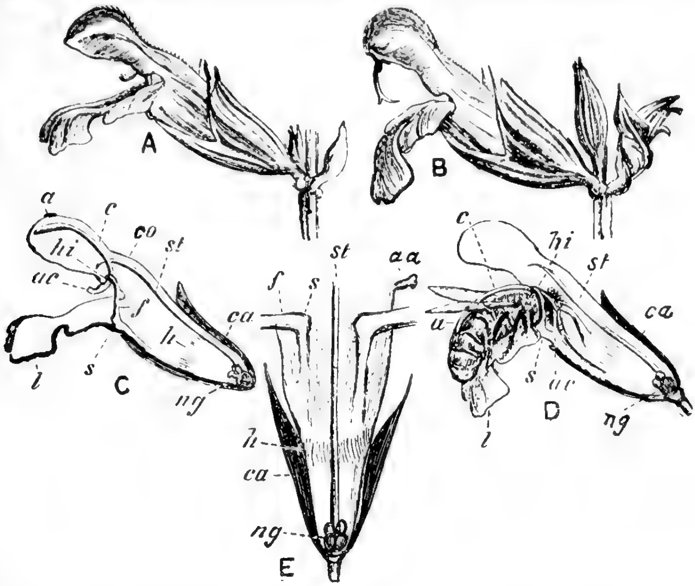

FIG. 1.—Flower of *Salvia officinalis*. (From Cheshire: *Bees and Bee-keeping*.)

A. Young flower, showing an atrophied pollen sac. B. Old flower, showing the stigma. C. Young, longitudinal section. D. Same visited by a bee. E. Longitudinal section, base of the corolla tube. *a* fertile pollen sac; *ac* sterile pollen sac; *c* connective which joins the two sacs and which can oscillate in *hi* around the filament of stamen *f*; *st* style; *ng* nectary at base of ovaries; *ca* calyx; *co* corolla.

as he enters, brushes off some pollen on the projecting stigma (*st*). With the exception of the *Salvia coccina*, studied by Ogle and Darwin, all the sages are thus fertilized by the bees.

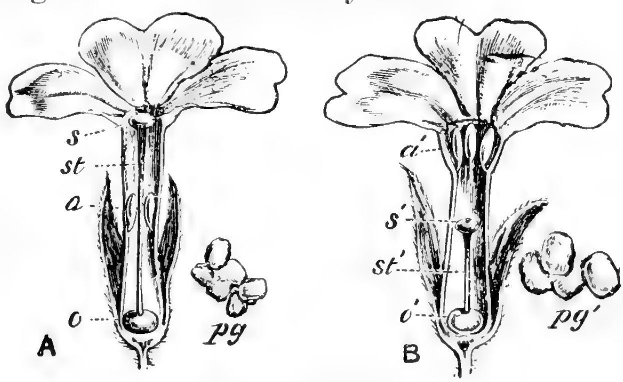

FIG. 2.—*Primula vulgaris.*

A. Flower with long style (*st*). B. Flower with short style (*st'*); *s s'* stigmala; *a a'* stamens; *o o'* ovaries; *pg pg'* grains of pollen.

Among the primroses we find a much larger and more varied class of plants equally adapted to cross fertilization by insects, but in a different manner. As illustrated in the *Primula vulgaris* (fig. 2) there are among these plants two sorts of flowers: Some (B) in which

the style (st') scarcely reaches beyond the middle of the tube of the corolla and the stamens (a') are placed near the orifice; others (A) where the position is reversed, the style (st) extending to the orifice and the stamens forming a ring in the center of the tube.

To this remarkable difference is added another hardly less curious; the pollen of the short-styled flowers is large grained (pg') while the pollen of the others comes in very small grains (pg). These plants are therefore as ill adapted as possible to direct fertilization or cross fertilization through the action of the wind. Some sort of insect intervention becomes almost necessary. When a bee goes into one of the short-styled flowers (B) he strikes the stamen with his head and covers it with pollen dust. When he enters a flower of the other sort

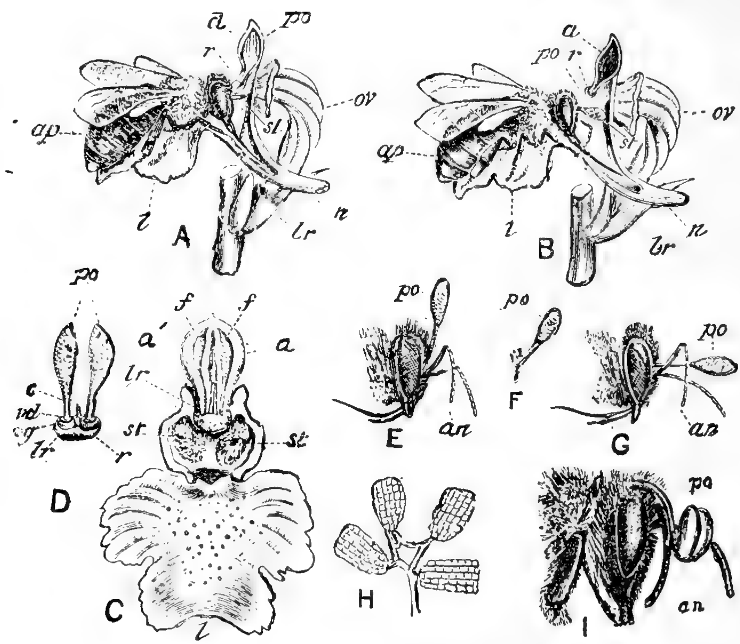

FIG. 3.—Orchid flowers and their fertilization by bees.

A. Flower of *Orchis morio*, with the sepals, two petals, and a bit of the right side of the spur removed. This flower is visited by a bee which receives on its face the sticky pollen mass from (r). B. This pollen is carried to another flower which receives it on its stigma (st), after which another mass (po) is carried away by the visitor. C. Same as A, viewed from front to show entrance to spurs and the antler (a). D. Isolated mass of pollen (po) fixed on the rostellum. E, F, G. Successive positions taken by pollen on bee's head. H. Disruption of pollen. I. *Vanda* pollen on head of honeybee.

(A) he brushes off on its stigma the large grains of pollen he carries and with his proboscis gathers the little grains which will fertilize the short-styled flowers. Darwin has made a profound study of these heterostyle plants and has demonstrated that their fertilization is almost always by crossing effected by the visits of insects.

Among the violets, the Aristolochiaceæ and many other Phanerogams, the arrangement of the parts of the flower renders even more necessary the intervention of insects, but I pass them over in order to reach the orchids, where in almost every case this intervention is absolutely necessary.

Figure 3 shows the details of an orchid: The great lip (*l*) of the corolla ends in a long spur which incloses the nectar-producing organs (*n*). Near the front of the spur the style expands into a double stigma, which hangs beneath the one large anther (*a*). Instead of being a diffused dust, the grains of pollen are closely connected and form two masses (*po*), which are joined by the stipes (*c*) to a glutinous body (*tr*) at the entrance of the spur. Except the *Ophrys apifera*, which, thanks to a special structure, can do so, the plants of this family are utterly incapable of self fertilization. Nor can the wind aid them. The pollen grains can easily be lifted up with a needle or pencil point from the glutinous mass where they are collected. It is by an analagous process that honey bees effect the cross-fertilization of these plants. On entering the spur in search of nectar they come into contact with the viscous disk (A) and generally carry off one or two of the pollen grains attached somewhere on the front portion of their body. As Darwin has shown, the sticky substance dries very quickly and when the insect

FIG. 4.—Transportation of orchid pollen masses by bees. (Pollen represented by diagonal lines.)

1. *Eulema dimidiata*. 2. *Eualossa cordata*.

enters the spur of another flower the mass is abandoned so that it becomes attached to the stigma, where it yields the fertilizing element.

The part that the insects play and the advantages of cross-fertilization among the orchids are shown with all possible clearness in the case of the vanilla. In Mexico this plant is fertilized naturally by different insects, especially by the Melipones, which greatly resemble our bees, but in other regions artificial fertilization is produced by rubbing the stamen on the pistil with a needle. M. Lecomte, who has studied the matter, attributes the superior quality of the Mexican vanilla to the advantage of natural cross-fertilization over artificial auto-fertilization. In our own greenhouses the vanilla plant has the same experiences—it can produce flowers, but no seed, without preliminary fertilization.

We must therefore conclude that the Anthophila, and particularly the Mellifera, have a place of no small importance in the fertilization of flowering plants. They give them the advantages of crossing, and in a large number of cases are absolutely essential to their reproduction.

Perhaps M. Perez exaggerated their importance a little when he said, with Dodel-Port, that "a hundred thousand species of plants would disappear from the face of the earth" if the bees ceased their visits, but no one can doubt that such a contingency would cause a very great disturbance in the vegetable kingdom.

We have now arrived at two facts of the first importance: Flowers are necessary to bees, and bees, on their side, are very useful or even necessary to the fertilization of flowering plants. It now remains to inquire whether this reciprocity of service has had as a consequence any reciprocal adaptation in the two sorts of beings.

It is generally admitted that all living things are subject to greater or less variation, and that among these variations those which are advantageous to the species are fixed and further developed by heredity and natural selection. So if flowers are necessary to the bees and bees are useful or necessary in the fertilization of flowers, it is

FIG. 5.—Side view of a honeybee.

only natural to suppose that all the variations which favor food collection in the former and reproduction in the latter will in the course of time be acquired and amplified. This is strictly reasonable; but science will not rest content with a priori generalizations, and we must discover how far this logical conclusion is justified by actual facts.

The adaption of the Mellifera to the collection of pollen and nectar appears in various degrees through the whole series from the Prosopis to the honeybee *Apis mellifera*. The structure of the former does not differ essentially from that of the wasps, only if the jaw appendages have been a little elongated and the hairs a little more numerous we are at the beginning of the real evolution of the Mellifera. In the honeybee, on the other hand, the evolution has reached its highest point and shows itself plainly in the adaptations. For the collection of pollen there are the collecting hairs which cover every part of the body and which, on the inside of the first tarsal joint

of the hind legs, are grouped to form a marvelous little brush. Little balls of pollen gathered together by this covering are received in a little basket-like depression on the outside face of these legs, where they accumulate and are held by a fringe of curved hairs until the workman, finding his ruffles growing too heavy, goes back to the hive to get rid of his burden. For the collection of nectar the adaptive modifications are even more perfect and more complicated. With the exception of the mandibles, all the buccal appendages are elongated and grouped so as to form a proboscis, which at rest is folded twice upon itself, and in action is half as long as the body. Hollowed out on the inner surface and stretched out to their fullest extent the jaw-boxes and the labial feelers are joined to form the sides of this organ; (fig. 6, nos. 3 and 4) in the axis is the tongue, sharp and rough, which is tipped with another tongue in miniature.

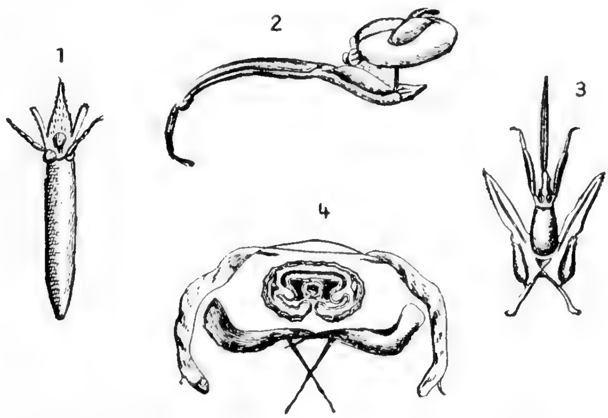

FIG. 6.—Buccal apparatus of bees. (According to H. Müller.)

1. Bee with short tongue, carried on a long chin (*Halictus quadricinctur*). 2. Head and proboscis of *Bombus hortorum*. 3. Jaws and lower lip of the common bee (*Apis mellifica*). 4. Cross section of the proboscis of the *Apis mellifica*.

This tip is creased into a narrow gutter on its ventral surface and is entirely covered with little absorbent hairs. No more suitable instrument could be devised for the collection of the liquid sugar in the nectaries, for these organs are usually deeply buried in the corolla, sometimes forming a circle at the base of the pistil, as in the Crucifer (fig. 8, no. 2), sometimes relegated to the lower end of the floral spur as in the orchid. (Fig. 4.) Thanks to the absorbent hairs on the little tongue, the nectar is drawn in through the capillary groove as far as the canal formed by the jawbones and the labial feelers, thence it goes to the upper surface and mounts to the mouth through the impulsion produced by the dilation and backward and forward movement of the tongue. In order to understand this mechanism one should watch bees when drinking water. A month ago at the Laboratory of Vegetable Biology I saw a large number thus occupied; gathered on a bit of moss which covered a little raft

they extended their proboscides and drank in the same way they collect nectar.

Between these and the Prosopis there is a long series in which we may see the instruments for collecting nectar improve step by step. With the Xylocopidae, the Anthophoridae, and the Euglossidae, we arrive at the Mellifera, where the social life does not yet exist, but where the proboscis equals in perfection, and sometimes even surpasses, in development that of the common bee. Among the Euglossidae it measures at least one and a half the length of the body.

The collection of pollen is effected by appendages which much resemble those of the Halictinae, only the hairs are short and more or less brush-like on the leg as well as on the first joint of the tarsus. These brushes approach those of the honeybee without attaining the same degree of perfection, for the differentiations which make the

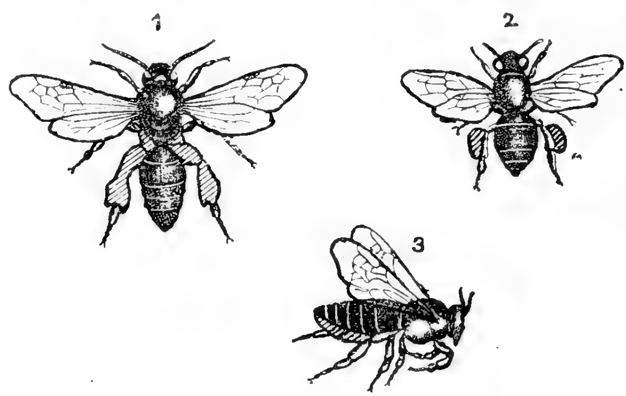

FIG. 7.—The transportation of pollen by the Mellifera. (The loads of pollen are indicated by diagonal lines.)

1. *Andrena clarkella.* 2. *Apis mellifica.* 3. *Megachile centuricularis L.* (Among the Megachiles, the pollen brush is on the ventral surface of the abdomen.)

basket has not yet taken place, and the double brush and the accompanying wrinkles must retain the pollen as well as collect it.

One step more and we arrive at the honey bee; here the brush on the leg has been replaced by the basket and that of the first tarsal joint serves only to collect the pollen dust. The insect no longer waits until he reaches the nest to mix this dust with the honey, but at the moment he collects he makes little balls which he carries in his basket. To respond to the exigencies of the social life the honey gatherer accumulates a reserve and has acquired a faculty of secreting a waxy matter which allows him to construct cells. However, these aptitudes are by no means equally developed in all the forms of the group; at the foot of the series are the bumble-bees who build without skill great ovoid cells where they raise their young and store their reserves. These reserves are never large and often insufficient to provide for the colony during the winter; this being the case, the colonies have a feeble con-

stitution and often disappear altogether at the approach of the bad season. Even the Mellifera are more industrious and farsighted than this. The reserve receptacles of their complicated nests in the tropical regions somewhat resemble the cells of the bumble-bees, but they are intended simply as magazines to hold enough provision to allow the colony to maintain itself when the flowers cease to bloom. Those of the honey bee are very different in character; they are intended exclusively for the subsistence of the young and consist of a stratum of cylindrical cells cleverly joined. This architecture brings us to that of the bees, properly speaking, which rises to the perfection of simplicity and economy of material. Here the cells are all of the same type and are intended for stroage as well as for the rearing of the young. They consist of hexagonal prisms separated by common walls, and in each comb is formed two opposite layers separated by a common base. No lost space, no materials wasted; these edifices are marvels of construction.

Among the four species of bees known to us an appreciable difference in industry may be noticed; the little *Apis florea* and the great *Apis dorsata* nest in the open air and build only a single comb; the *Apis indica* constructs parallel combs, frequently in cavities, but nevertheless readily accessible to Teigius and other enemies; finally, our honey bee builds in the same way, but better protects his work by carefully driving away all parasites.

Thus, from Prosopis to the honeybee, we find a series growing more and more perfect by degrees. These forms, developed in the course of time, recall the various evolutionary stages through which the honey bees have passed, and show how these insects unquestionably adapt themselves to the flowers. The apiarists know that the honeybees are not all equally adapted for nectar gathering, and that certain of them collect more advantageously than others with longer tongues; they have even invented a special apparatus, the glossometer, to measure the length of that organ. By rigorous selection these bee keepers hope to fix a form in which the tongue will attain its highest development. They will then be in possession of the race best suited to the pursuit of nectar. With their marvelous instincts, how invaluable will be our bees when they can get rid of the very long proboscis of the Euglossidae?

Here we enter into the domain of hypothesis, but without departing from probability, for the honeybee is an essentially variable creature. Native to Asia,[a] like all the other species of the genus, they are now found all over the world from the equator to the extreme limits of the temperate zones. Our black bee is already very different

[a] This is true of the *Apis florea*, *A. dorsata*, and *A. indica*, but not so clearly established for the ordinary bee, *Apis mellifica*.

from the Italian variety with its yellow fuzz, but both are even still farther removed from the tropical bees, especially those of the islands. Careful study is necessary to assign all these varieties to the same type; there are thirty forms, most of which have been taken by many zoologists for distinctive species.

To-day hardly anyone disputes the adaptation of bees to food-gathering in the flowers, but the adaptation of the flowers to these visitors remains an object of heated controversy. One of the schools, headed by Darwin and Sir John Lubbock, exaggerates the influence, while the other, M. Gaston Bonnier and his pupils, denies its existence.

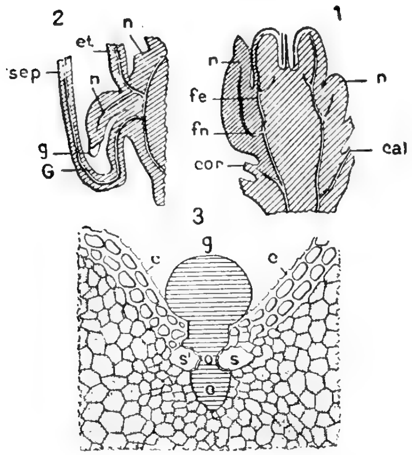

FIG. 8.—Nectaries and exudation of nectar, much enlarged. (After Gaston Bonnier.)

1. Longitudinal cross section of the *Salvia lantanifolia: cal*, insertion of the calyx; *cor*, insertion of the petals; *n*, nectaries with carpels; *fe*, vessels leading to carpels; *fn*, vessels leading to nectaries. 2. Longitudinal cross section of *Aubrietia columnae: sep*, sepals; *et*, stamens; *n*, *n*, nectaries; *g*, drop of nectar falling into reservoir. 3. Nectary of a peach flower, showing the nectar (*g*) which accumulates in the chamber (*c*) of a stoma.

Before entering upon this delicate question let me recall the passage in which Sir John Lubbock has fixed its extent and portent. "Not only," says he, "have the form and the colors, the bright tints, the sweet odors, and the nectar been gradually developed by force of an unconscious selection exercised by the insects, but even the arrangement of the colors, the shape, the size and the position of the petals, the relative position of the stamens and pistil, are all determined by the visits of the insects, and in such a way as to assure the great object (fertilization) that these visits are intended to effect."

In his beautiful work on the nectaries, Gaston Bonnier has furnished numerous irrefutable arguments against the theory that that nectar is an adaptation to attract insects. According to this author the nectaries are organs of reserve where the cane sugar, dissolved in the cellular juice, is elaborated and stored. As night falls, closing the air-stomata and arresting the chlorovaporization, the emission of water vapor by the plant is replaced by a sort of sweating, which comes slowly from all points of the surface and the nectaries in the form of little drops more or less rich in sugar. Thus the drops of nectar have the same origin as the water given forth by the water-carrying stomata. They are the result of a stoppage in the transpiration and do not present any peculiar character other than that of having traversed organs rich in sac-

charines. The nectar never contains more than a small part of the sugar secreted by the nectaries.

When the insects do not collect the nectar soon after its emission it is reabsorbed by the plant and serves to nourish the tissues and to develop the organs, especially those for the formation of seeds. In a word, it is for its own use, and not to attract bees for fertilization, that the plant secretes nectar. It thereby accumulates reserves at the points nearest to the place of utilization. Ordinarily this is in the flower, where it best can serve the development of the seeds, but sometimes it is in other parts of the body, where it is more needed.

It is therefore impossible to consider nectar and the nectaries entirely as the products of an adaptation which would have as its result the attraction of insects to its flowers. Sir John Lubbock seems to me wrong on this point.

I am not so certain about the odor. Whether it come from petals or nectar, no one can doubt that it attracts the keen-sensed bees. Their olfactory sensibility is demonstrated by the ability they show in discovering honey in the closest places. In the small house in which is kept the honey taken from the hives, at the Laboratory of Vegetable Biology, I saw hundreds of bees. The building was perfectly tight and all the chinks in the windows stopped up, and in spite of assiduous search it was impossible to discover the fissure which gave entrance to the swarm. As an additional bit of evidence, M. Perez very justly observes that bees frequenting the willow catkins in the early spring always come thither from the side toward which the wind blows the fragrance.

I do not forget that Sir John Lubbock has seen bees indifferent to a bit of honey placed but a short distance from their hive, but believe that Perez exactly interprets this experience when he says that the collector bee at the moment when it goes out to work is "exclusively absorbed by the idea of its work," and that it is "indifferent to all which is not the object of its activity of the moment." Nor do I ignore the fact that Gaston Bonier finds an objection to the theory of attraction by perfumes in the bee's indifference to the delicate fragrance of the *Melittis melissophyllum*. But I also know that all flowers are not equally attractive and that the Melittis is a plant for which the bees show little taste.

We will therefore admit with a great majority of the naturalists that the odor of flowers is an element of attraction for insects. As a consequence is it necessary to believe with Darwin and Sir John Lubbock that these perfumes are the product of an adaptation of the flowers to the insect? It is rather bold to commit oneself to the affirmative when so many plants are strongly scented in places other

than their flowers. However, the vastly greater frequency with which these perfumes are found in flowers leads one to admit that the theory of the English authors has at least a great degree of probability. In any case no one will deny that the perfume in flowers does attract insects, especially the honeybee.

Still more evident is the attraction of the colors in flowers. Who has not seen bees flying through the fields choosing the favorite flowers and disdaining all others? Numbers of cases have been cited in which the bee evidently associated the notion of color with the idea of booty, and in which the tints of the flowers alone served him as a guide.

I would not dwell on this question had not two eminent naturalists, Gaston Bonier and Plateau, denied "that, all other things being equal, brilliant colors in preference to those of duller shade attract insects." Plateau covered a dahlia, little by little, with green leaves and observed that the bees continued their visits to the flowers in spite of their green color. Monsieur Forel tried the same experiment by pinning green leaves over twenty-eight out of fifty-three flowers of various colors displayed in the same basket. He found that the bees immediately ceased visiting the covered ones (and neglected them for two hours until one bee discovered the stratagem), and within a short time they were visited like the free blossoms. "Plateau, therefore, has experimented badly and drawn false conclusions," says Monsieur Forel. "When he covered his dahlias he covered them slowly and only on top. The bees perceived the trick and could still see the sides of the dahlias. Plateau had failed to reckon with the memory and the attention of the bees."

Gaston Bonnier experimented differently. On a smooth bit of green turf about 20 m. from some hives he placed a row of rectangles about 2 m. apart. These blocks, measuring 22 by 12 cm., were red, green, white, or yellow, and all daubed with the same quality of honey. They were impartially visited by the bees, with apparently a slight preference for the green. In considering this experiment one should not forget that there was absolutely no reason why bees absorbed in the search of nectar or pollen should visit these great colored rectangles which in nowise resembled flowers of any kind.

Monsieur Forel introduced into a basket of dahlias a number of large artificial flowers in the heart of which he placed a bit of honey. The bees were satisfied with the dahlias until one of their number wandered into the artificial flowers. As he repeated his trip he was imitated by others until the dahlias were deserted and all the imitations were visited except those colored green; this continued even when the artificial flowers had been despoiled of their honey. All the brilliant imitation attracted the bees; all of the green ones were unnoticed. But, in drawing his deductions, I believe Forel is wrong in not ascribing to bees a keen enough perception of odors; he forgets,

as does Bonnier, when he offers as an argument against the attractions of color their visits to green catkins and honey-smeared leaves, that bees allow themselves to be guided by all their senses, and do not depend on smell or sight alone.

It seems, then, quite certain that the honey bees are attracted by color in flowers, but not so certain that color is an adaptation of the plant to the insect. Although the latter is believed by many of the most distinguished naturalists it still wants conclusive demonstration. Like the odor the adaptation does exist, but more than that can not be said positively. However this may be, both of these agents serve to attract the bees and in this way favor the fertilization of the phanerogams.

This is even more true of the variously complicated flowers—the long-tubed corolla, the narrow spurs, the stamens covered by the petals. Granted that over and above the attraction they exercise on the bees, the color and perfume of a flower may play some part in the adaptation of a plant, the same can not be said with regard to these complications of the calyx and corolla. How can the infinite variety of these organs and their sometimes fantastic arrangement be explained without recourse to the hypothesis of a reaction of the plant toward the insect? This reaction began the day the first insects visited the first flowers and is continued through the present.

To summarize: (1) Nectar and the nectaries are certainly intended primarily for the plant itself and do not prove an adaptation of the flower to the insects. (2) The colors and perfumes of flowers may be, perhaps, the result of such an adaptation, but in any case they strongly attract anthophilian insects, signalling to them the presence of booty. (3) In many cases, if not all, the complicated forms of the flowers must be attributed to the adaptation of flowers to their visitors.

Such is the state of our knowledge as it stands to-day, founded, I think, on the closest observation and the best reasoning. In the very nature of things adaptation requires long evolutionary periods; it can rarely be proved directly, and evidence regarding it is only to be obtained by long comparative observations.

However, it is almost unanimously conceded nowadays that the Mellifera, at least in so far as their collecting aparatus is concerned, are beautifully adapted to the flowers, but, despite the fact that practice has shown that plants are in every way more plastic than animals, it is still strongly disputed that the flowering plants have adapted themselves to bees.

If there does exist any reciprocal modification between the Mellifera and the flowering plants it is not at all necessary to suppose that one group has been modified for the benefit of the other. Each has evolved on its own account. Explained thus, the many objections

to the theory of reciprocal adaptation are overthrown. The bee has but one object, the pursuit of food, and all things which aid him in it are welcome. Usually the plant profits thereby; sometimes it suffers. On the other hand, the plant seeks only to assure its propagation and all of its modifications tend only toward that goal. It is only indirectly that the colors and perfumes are of advantage to insects; the complicated flower, most favorable to the reproduction of the plant, is to the bees an obstacle. The cleistogamous flowers give a striking proof of the independence of a plant so far as insects are concerned. These tiny, feeble flowers are close-fertilized without any intervention; insects never visit them. Found generally among normal flowers, they prove that plants seek by all possible means to render fertilization inevitable.

Claude Bernard has splendidly formulated this truth in an aphorism quoted by M. Gaston Bonnier in his work on the nectaries: "The law of the physiological finality is in each individual being and not outside it; the living organism is made for itself; it has its own intrinsic laws. It works for itself and not for others." It is not possible better to define the reciprocal adaptations which we have shown exists between bees and flowers. It is by no means for the benefit of the plant that the collecting apparatus of the bees is modified, but only that the bee may better nourish itself. On the other hand, it is to the distinct advantage of the plant and its propagation that flowers are modified in shape, color, and odor. The insect has gained by the conformation of the flowers; the flower by the visits of the insect. But each of these beings has been evolved on its own account and adapted itself, as pointed out by the illustrious Lamarck, to the vital conditions of the world in which it lives.

THE PEARL FISHERIES OF CEYLON.[a]

By Prof. W. A. Herdman, D. Sc., F. R. S.

The celebrated pearl "oysters" of Ceylon are found mainly in certain parts of the wide, shallow plateau which occupies the upper end of the Gulf of Manaar, off the northwest coast of the island and south of Adams Bridge.

The animal (*Margaritifera vulgaris*, Schum. = *Avicula fucata*, Gould) is not a true oyster, but belongs to the family Aviculidæ, and is therefore more nearly related to the mussels (*Mytilus*) than to the oysters (*Ostræa*) of our seas.

The fisheries are of very great antiquity. They are referred to by various classical authors, and Pliny speaks of the pearls from Taprobane (Ceylon) as "by far the best in the world." Cleopatra is said to have obtained pearls from Aripu, a small village on the Gulf of Manaar, which is still the center of the pearl industry. Coming to more recent times, but still some centuries back, we have records of fisheries under the Cingalese kings of Kandy, and subsequently under the successive European rulers—the Portuguese being in possession from about 1505 to about 1655, the Dutch from that time to about 1795, and the English from the end of the eighteenth century onward. A notable feature of these fisheries under all administrations has been their uncertainty.

The Dutch records show that there were no fisheries between 1732 and 1746, and again between 1768 and 1796. During our own time the supply failed in 1820 to 1828, in 1837 to 1854, in 1864 and several succeeding years, and, finally, after five successful fisheries in 1887, 1888, 1889, 1890, and 1891, there has been no return for the last decade. Many reasons, some fanciful, others with more or less basis of truth, have been given from time to time for these recurring failures of the fishery, and several investigations, such as that of Doctor Kelaart

[a] Address before the Royal Institution of Great Britain, Friday, March 27, 1903. Here reprinted from author's revised copy. The official report upon this investigation is now being published for the Ceylon government by the Royal Society of London.

(who unfortunately died before his work was completed) in 1857 to 1859 and that of Mr. Holdsworth in 1865 to 1869, have been undertaken without much practical result so far.

In September, 1901, Mr. Chamberlain asked me to examine the records and report to him on the matter, and in the following spring I was invited by the Government to go to Ceylon with a scientific assistant and undertake any investigation into the condition of the banks that might be considered necessary. I arrived at Colombo in January, 1902, and, as soon as a steamer could be obtained, proceeded to the pearl banks. In April it was necessary to return to my university duties in Liverpool, but I was fortunate in having taken out with me as my assistant Mr. James Hornell, who was to remain in Ceylon for at least a year longer in order to carry out the observations and experiments we had arranged and complete our work. This programme has been carried out, and Mr. Hornell has kept me supplied with weekly reports and with specimens requiring detailed examination.

The Ss. *Lady Havelock* was placed by the Ceylon government at my disposal for the work of examining into the biological conditions surrounding the pearl oyster banks, and this enabled me on two successive cruises of three or four weeks each to examine all the principal banks and run lines of dredging and trawling and other observations across, around, and between them, in order to ascertain the conditions that determine an oyster bed. Toward the end of my stay I took part in the annual inspection of the pearl banks, by means of divers, along with the retiring inspector, Capt. J. Donnan, C. M. G., and his successor Captain Legge. During that period we lived and worked on the native bark *Rangasameeporawee* and had daily opportunity of studying the methods of the native divers and the results they obtained.

It is evident that there are two distinct questions that may be raised—the first as to the abundance of the adult "oysters" and the second as to the number of pearls in the oysters, and it was the first of these rather than the frequency of the pearls that seemed to call for investigation, since the complaint has not been as to the number of pearls per adult oyster, but as to the complete disappearance of the shellfish. I was indebted to Captain Donnan for much kind help during the inspection, when he took pains to let me see as thoroughly and satisfactorily as possible the various banks, the different kinds and ages of oysters, and the conditions under which these and their enemies exist. I wish also to record my entire satisfaction with the work done by Mr. Hornell, both while I was with him and also since. It would have been quite impossible for me to

have got through the work I did in the very limited time had it not been for Mr. Hornell's skilled assistance.[a]

Most of the pearl oyster banks or "paars" (meaning rock or any form of hard bottom, in distinction to "manul," which indicates loose or soft sand) are in depths of from 5 to 10 fathoms and occupy the wide shallow area of nearly 50 miles in length, and extending opposite Aripu to 20 miles in breadth, which lies to the south of Adam's Bridge. On the western edge of this area there is a steep declivity, the sea deepening within a few miles from under 10 to over 100 fathoms, while out in the center of the southern part of the Gulf of Manaar, to the west of the Chilaw Pearl Banks, depths of between 1,000 and 2,000 fathoms are reached. On our two cruises in the *Lady Havelock* we made a careful examination of the ground in several places outside the banks to the westward, on the chance of finding beds of adult oysters from which possibly the spat deposited on the inshore banks might be derived. No such beds outside the known "paars" were found, nor are they likely to exist. The bottom deposits in the ocean abysses to the west of Ceylon are "globigerina ooze" and "green mud," which are entirely different in nature and origin from the coarse terrigenous sand, often cemented into masses, and the various calcareous neritic deposits, such as corals and nullipores, found in the shallow water on the banks. The steepest part of the slope from 10 or 20 fathoms down to about 100 fathoms or more all along the western coast seems in most places to have a hard bottom covered with Alcyonaria, sponges, deep-sea corals, and other large encrusting and dendritic organisms. Neither on this slope nor in the deep water beyond the cliff did we find any ground suitable for the pearl oyster to live upon.

Close to the top of the steep slope, about 20 miles from land, and in depths of from 8 to 10 fathoms, is situated the largest of the "paars," the celebrated Periya Paar, which has frequently figured in the inspector's reports, has often given rise to hopes of great fisheries, and has as often caused deep disappointment to successive Government officials. The Periya Paar runs for about 11 nautical miles north and south, and varies from 1 to 2 miles in bredth, and this—for a paar—large extent of ground becomes periodically covered with young oysters, which, however, almost invariably disappear before the next inspection. This paar has been called by the natives the "mother paar" under the impression that the young oysters that come and go in fabulous numbers migrate or are carried inward and supply the inshore paars with their populations. During a careful investigation of the Periya Paar and its surroundings

[a] Mr. Hornell is now marine biologist to the Ceylon government and inspector of the pearl banks.—W. A. H. January, 1905.

we satisfied ourselves that there is no basis of fact for this belief; and it became clear to us that the successive broods of young oysters on the Periya Paar, amounting probably within the last quarter century alone to many millions of millions of oysters, which if they had been saved would have constituted enormous fisheries, have all been overwhelmed by natural causes, due mainly to the configuration of the ground and its exposure to the southwest monsoon.

The following table shows, in brief, the history of the Periya Paar for the last twenty-four years:

Feb., 1880. Abundance of young oysters.
Mar., 1882. No oysters on the bank.
Mar., 1883. Abundance of young oysters, 6 to 9 months old.
Mar., 1884. Oysters still on bank, mixed with others of 3 months old.
Mar., 1885. Older oysters gone, and very few of the younger remaining.
Mar., 1886. No oysters on bank.
Nov., 1887. Abundance of young oysters, 2 to 3 months.
Nov., 1888. Oysters of last year gone and new lot come, 3 to 6 months.
Nov., 1889. Oysters of last year gone; a few patches 3 months old present.
Mar., 1892. No oysters on the bank.
Mar., 1893. Abundance of oysters of 6 months old.
Mar., 1894. No oysters on the bank.
Mar., 1895. Ditto.
Mar., 1896. Abundance of young oysters, 3 to 6 months.
Mar., 1897. No oysters present.
Mar., 1898. Ditto.
Mar., 1899. Abundance of oysters, 3 to 6 months old.
Mar., 1900. Abundance of oysters 3 to 6 months old; none of last year's remaining.
Mar., 1901. Oysters present of 12 to 18 months of age, but not so numerous as in preceding year.
Mar., 1902. Young oysters abundant, 2 to 3 months. Only a few small patches of older oysters (2 to $2\frac{1}{2}$ years) remaining.
Nov., 1902. All the oysters gone.

It is shown by the above that since 1880 the bank has been naturally restocked with young oysters at least eleven times without yielding a fishery.

The 10-fathom line skirts the western edge of the paar, and the 100-fathom line is not far outside it. An examination of the great slope outside is sufficient to show that the southwest monsoon running up toward the Bay of Bengal for six months in the year, must batter with full force on the exposed seaward edge of the bank and cause great disturbance of the bottom. We made a careful survey of the Periya Paar in March, 1902, and found it covered with young oysters a few months old. In my preliminary report to the Government, written in July, I estimated these young oysters at not less than 100,000 millions, and stated my belief that these were doomed to destruction and ought to be removed at the earliest opportunity to a

safer locality further inshore. Mr. Hornell was authorized by the governor of Ceylon to carry out this recommendation, and went to the Periya Paar early in November with boats and appliances suitable for the work, but found he had arrived too late. The southwest monsoon had intervened, the bed had apparently been swept clean, and the enormous population of young oysters, which we had seen in March, and which might have been used to stock many of the smaller inshore paars, was now in all probability either buried in sand or carried down the steep declivity into the deep water outside. This experience, taken along with what we know of the past history of the bank as revealed by the inspectors' reports, shows that whenever young oysters are found on the Periya Paar they ought, without delay, to be dredged up in bulk and transplanted to suitable ground in the Cheval district—the region where the most reliable paars are placed.

From this example of the Periya Paar it is clear that in considering the vicissitudes of the pearl oyster banks we have to deal with great natural causes which can not be removed, but which may to some extent be avoided, and that consequently it is necessary to introduce large measures of cultivation and regulation in order to increase the adult population on the grounds, give greater constancy to the supply, and remove the disappointing fluctuations in the fishery.

There are in addition, however, various minor causes of failure of the fisheries, some of which we are able to investigate. The pearl oyster has many enemies, such as star-fishes, boring sponges which destroy the shell, boring mollusks which suck out the animal, internal Protozoan and Vermean parasites and carnivorous fishes, all of which cause some destruction and which may conspire on occasions to ruin a bed and change the prospects of a fishery. But in connection with such zoological enemies it is necessary to bear in mind that from the fisheries point of view their influence is not wholly evil, as some of them are closely associated with pearl production in the oyster. One enemy (a Plectognathid fish) which doubtless devours many of the oysters, at the same time receives and passes on the parasite which leads to the production of pearls in others. The loss of some individuals is in that case a toll that we very willingly pay, and no one would advocate the extermination of that particular enemy.

In fact, the oyster can probably cope well enough with its animate environment if not too recklessly decimated at the fisheries, and if man will only compensate to some extent for the damage he does by giving some attention to the breeding stock and "spat," and by transplanting when required the growing young from unsuitable ground to known and reliable "paars."

Those were the main considerations that impressed me during our work on the banks, and, therefore, the leading points in the conclu-

sions given in my preliminary report (July, 1902) to the governor of Ceylon ran as follows:

1. The oysters we met with seemed, on the whole, to be very healthy.

2. There is no evidence of any epidemic or of much disease of any kind.

3. A considerable number of parasites, both external and internal, both Protozoan and Vermean, were met with, but that is not unusual in mollusks, and we do not regard it as affecting seriously the oyster population.

4. Many of the larger oysters were reproducing actively.

5. We found large quantities of minute "spat" in several places.

6. We also found enormous quantities of young oysters a few months old on many of the paars. On the Periya Paar the number of these probably amounted to over 100,000 million.

7. A very large number of these young oysters never arrive at maturity. There are several causes for this.

8. They have many natural enemies, some of which we have determined.

9. Some are smothered in sand.

10. Some grounds are much more suitable than others for feeding the young oysters, and so conducive to life and growth.

11. Probably the majority are killed by overcrowding.

12. They should therefore be thinned out and transplanted.

13. This can be easily and speedily done, on a large scale, by dredging from a steamer, at the proper time of year, when the young oysters are at the best age for transplanting.

14. Finally, there is no reason for any despondency in regard to the future of the pearl oyster fisheries, if they are treated scientifically. The adult oysters are plentiful on some of the paars and seem for the most part healthy and vigorous, while young oysters in their first year, and masses of minute spat just deposited, are very abundant in many places.

To the biologist two dangers are, however, evident, and, paradoxical as it may seem, these are overcrowding and overfishing. But the superabundance and the risk of depletion are at the opposite ends of the life cycle, and therefore both are possible at once on the same ground—and either is sufficient to cause locally and temporarily a failure of the pearl oyster fishery. What is required to obviate these two dangers ahead and insure more constancy in the fisheries, is careful supervision of the banks by some one who has had sufficient biological training to understand the life problems of the animal, and who will therefore know when to carry out simple measures of farming, such as thinning and transplanting, and when to advise as to the regulation of the fisheries.

In connection with cultivation and transplantation, there are various points in structure, reproduction, life-history, growth and habits of the oyster which we had to deal with, and some of which we were able to determine on the banks, while others have been the subject of Mr. Hornell's work since, in the little marine laboratory we established at Galle.

Although Galle is at the opposite end of the island form the pearl banks or Manaar, it is clearly the best locality in Ceylon for a marine laboratory—both for general zoology and also for working at pearl oyster problems. Little can be done on the sandy exposed shores of Manaar island or the Bight of Condatchy—the coasts opposite the pearl banks. The fisheries take place far out at sea, from 10 to 20 miles off shore; and it is clear that any natural history work on the pearl banks must be done not from the shore, but as we did, at sea from a ship during the inspections, and can not be done at all during the monsoons because of the heavy sea and useless exposed shore. At such times the necessary laboratory work supplementing the previous observations at sea can be carried out much more satisfactorily at Galle than anywhere in the Gulf of Manaar.

Turning now from the health of the oyster population on the "paars," to the subject of pearl formation, which is evidently an unhealthy and abnormal process, we find that in the Celyon oyster there are several distinct causes that lead to the production of pearls. Some pearls or pearly exerescences on the interior of the shell are due to the irritation caused by boring sponges and burrowing worms. French writers have made similar observations in the case of Donax and other Lamellibranchs; and Dubois (1901) has more recently ascribed the production of pearls in mussels on the French coast, to the presence of the larva of Distomum margaritarum. Jameson (1902) then followed with a more detailed account of the relations between the pearls in Mytilus and the Distomid larvæ, which he identifies as Distomum (Brachycœlium) somateriæ (Levinson). Jameson's observations were made on mussels obtained partly at Billiers (Morbihan), a locality at which Dubois had also worked, and partly at the Lancashire Sea-Fisheries marine labortory at Piel in the Barrow Channel. Finally, Dubois has just published a further note in which, referring to the causation of pearls in Mytilus, he says: "En somme ce que ce dernier [Garner] avait vu en Angleterre en 1871, je l'ai retrouvé en Bretagne en 1901. Quelques jours après mon départ de Billiers, M. Lyster Jameson, de Londres, est venu dens la même localité et a confirmé le fait observé par Garner et par moi." But Jameson has done rather more than that. He has shown that it is probable (his own words are "there is hardly any doubt") that the parasite causing the pearl-formation in our

common mussel (not in the Ceylon "pearl oyster") is the larva of Distomum somateriæ, from the eider duck and the scoter. He also believes that the larva inhabits Tapes or the cockle as a first host before getting into the mussel.

We have found, as Kelaart did, that in the Ceylon pearl oyster there are several different kinds of worms commonly occurring as parasites, and we shall, I think, be able to show in our final report that Cestodes, Trematodes, and Nematodes are all concerned in pearl formation. Unlike the case of the European mussels, however, we find so far that in Ceylon the most important cause is a larval Cestode of the Tetrarhynchus form. Mr. Hornell has traced a considerable part of the life history of this parasite from an early free-swimming stage to a late larval condition in the file fish (Balistes mitis) which frequents the pearl banks and preys upon the oysters. We have not yet succeeded in finding the adult, but it will probably prove to infest the sharks or other large Elasmobranchii which devour Balistes.

It is only due to my excellent assistant, Mr. James Hornell, to state that our observations on pearl formation are mainly due to him. During the comparatively limited time (under three months) that I had on the banks I was mainly occupied with what seemed the more important question of the life conditions of the oyster, in view of the frequent depletion of particular grounds.

It is important to note that these interesting pearl-formation parasites are not only widely distributed over the Manaar banks, but also on other parts of the coast of Ceylon. Mr. Hornell has found Balistes with its Cestode parasite both at Trincomalie and at Galle, and the sharks also occur all around the island, so that there can be no question as to the probable infection of oysters grown at these or any other suitable localities.

There is still, however, much to find out in regard to all these points and other details affecting the life of the oyster and the prosperity of the pearl fisheries. Mr. Hornell and I are still in the middle of our investigations, and this must be regarded as only a preliminary statement of results which may have to be corrected, and I hope will be considerably extended in our final report.

It is interesting to note that the Ceylon Government Gazette of December 22 last announced a pearl fishery to commence on February 22, during which the following banks would be fished: The Southeast Cheval Paar, estimated to have 49 million oysters; the East Cheval Paar, with 11 millions; the Northeast Cheval Paar, with 13 millions; the Periya Paar Kerrai, with 8 million—making in all over 80 million oysters.

That fishery is now in progress, Mr. Hornell is attending it, and

we hope that it may result not merely in a large revenue from pearls,[a] but also in considerable additions to our scientific knowledge of the oysters.

As an incident of our work in Ceylon, it was found necessary to fit up the scientific man's workshop—a small laboratory on the edge of the sea—with experimental tanks, a circulation of sea water, and facilities for microscopic and other work. For several reasons, as was mentioned above, we chose Galle, at the southern end of Ceylon, and we have every reason to be satisfied with the choice. With its large bay, its rich fauna, and the sheltered collecting ground of the lagoon within the coral reef it is probably one of the best possible spots for the naturalist's work in eastern tropical seas.

In the interests of science it is to be hoped, then, that the marine laboratory at Galle will soon be established on a permanent basis, with a suitable equipment. It ought, moreover, to be of sufficient size to accommodate two or three additional zoologists, such as members of the staff of the museum and of the medical college at Colombo or scientific visitors from Europe. The work of such men would help in the investigation of the marine fauna and in the elucidation of practical problems, and the laboratory would soon become a credit and an attraction to the colony. Such an institution at Galle would be known throughout the scientific world, and would be visited by many students of science, and it might reasonably be hoped that in time it would perform for the marine biology and the fishing industries of Ceylon very much the same important functions as those fulfilled by the celebrated gardens and laboratory at Peradeniya for the botany and associated economic problems of the land.

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[a] It was a most successful fishery. A still larger one, bringing in over a million rupees to the Government, was held in 1904, and there are now excellent prospects for an important fishery in the spring of 1905.—W. A. H., January, 1905.

FLYING FISHES AND THEIR HABITS.

By Theodore Gill.

Flight is a preeminent attribute of terrestrial animals and is more especially associated by most persons with the birds, but it is by no means an uncommon faculty. Indeed, not to be able to fly is the exception for land animals, if number of species determine such a problem. This will be evident when it is remembered that all but a small percentage of insects fly, and insects are far more numerous than all other inhabitants of the land combined. Furthermore, the birds, whose chief attribute is the power of flight and adaptation therefor, are more numerous than all other terrestrial vertebrates together. We may repeat, therefore, that non-flight is exceptional and flight the normal provision for animals generally; flight, indeed, has been developed anew, time after time, in animals with limbs of the ambulatorial type.

The power of flight is also generally attributed to certain fishes, and it is interesting and significant that the adaptation and power which enable fishes to course through the air have also been developed in several entirely distinct groups. The faculty exists in its greatest perfection in two widely distinct families, one (the Exocœtids) being unarmed, soft-finned fishes of the group called Synentognathi and the other (the Dactylopterids) being armed acanthopterygian fishes related to the Gurnards. There are other fishes—among them relations of the Exocœtines and Dactylopterids—which have the power of progressing through the air to some extent, but their power to do so is so much less than those generally called flying fishes that they need not be considered here. Those to be now described will therefore be confined to the two families indicated—the Exocœtids and Dactylopterids.

In all the flying fishes the power of flight, or rather sustentation in the air, is effected in the same manner, that is, by the elongation of

the rays of the pectoral fins and a corresponding extension of the inter-radial membrane.[a] By this amplification of surface the fishes are buoyed up in the air. The pectoral fins are not used in the impulse which takes them out of the water; the sole impelling organ is the caudal fin. The muscles of the pectoral fins of flying fishes are little, if any, more developed than in fishes having normally strong pectorals. This weakness of the muscles operating the pectoral members contrasts remarkably with the great development of the pectoral and other muscles which impart the power of real flight to bats and birds.

A noteworthy coincidence is the limitation of flying fishes to the ocean—the great expanse of waters. None are found in bodies of fresh water, however large they may be, and this is equally applicable to the tropical sea lake of Tanganyika as it is to the northern Lake Superior. The only approximate exception has been indicated by the French traveler, Jacques Savorgnan de Brazza, who claimed that the little *Pantodon buchholzi* of the fresh waters of West Africa has the faculty of emerging from the water and sustaining itself for a short time in the air; thus it may be regarded to some extent as "a fresh water flying fish," as Boulenger has stated. The extent of the Pantodon's aerial excursions must be very limited, however, as the extension of the pectoral fins is comparatively limited; in fact, its excursions must be leaping rather than flying.

This *Pantodon* (*P. buchholzi*) is the sole known representative of a peculiar African family, the Pantodontids, related to the Osteoglossids. The only authority for considering it a flying fish is the designation given to it by the French traveler, Jacques Savorgnan de Brazza. He obtained a single specimen at Nganchou (or Gantshu), on the Congo, while obtaining water for drinking, and it was exhibited in a collection made by him as a flying fish ("petit poisson volant").[b] As such it is illustrated in the Cambridge Natural History (VII, 559) by Boulenger, who calls attention to it as "observed by M. de Brazza to be a freshwater flying fish." The fish only attains a length of about 4 inches.

The very words of the travelers and others, whose observations have been utilized, are preserved when the continuity of the narrative permits.

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[a] The rays to some extent correspond to or are homologous with the digits of the wing of a bat or bird, and the "wing" of a fish is therefore more like that of a bat than that of a bird; the wing of the fish, however, corresponds only to the distal portion of the bat's wing—that beyond the carpel bend.

[b] Revue Scientifique, t. 38, p. 18, 1886.

I. THE EXOCŒTOID FLYING FISHES.

I.

The Exocœtids, or true flying-fish family, manifest considerable diversity in form and in extension of the jaws, but agree in having the supramaxillaries only in contact (and not united) with the intermaxillaries, lower pharyngeals united in a broad triangular body, third pair of upper pharyngeals much enlarged, and the vertebrae destitute of zygapophysoid processes. They naturally fall into three groups or subfamilies, the Flying fishes proper or Exocœtines, the Sauries or Scomberesocines, and the Halfbeaks or Hemirhamphines.

Another very characteristic feature is the course of the lateral line; this is developed low down on each side of the abdomen and above the anal fin to the lower lobe of the caudal.

The flying fishes proper, or Exocœtines, have both jaws rounded or simply angulated in front, and the pectoral fins are generally greatly enlarged and adapted to the sustentation of the body in the air. Notwithstanding this striking specialization of the group, there are considerable differences. All agree, however, but in various degrees, in provision for emergence by leaping from the water and for progress in the air.

The form is adapted for the life most of them lead; the subfusiform shape, with a quadrate periphery and with the sharp cut front, is fitted for progress in water as well as air with the least friction. The elongated lower lobe of the caudal enables a final strong upward impulse to be given to the leaping fish; the pectoral and ventral fins are enlarged with the maximum of surface to sustain the body in the air and the minimum of weight in the framework. Their foremost rays are also sharp edged forward so as to act, in analogy with cutwaters, as "cutairs" as well as cutwaters. The air bladder is greatly enlarged and filled with a gaseous emanation (mostly nitrogen), which diminishes the relative weight of the body.

The flying fishes are mostly true pelagic animals, and some—one or more—may be met with in midocean in every tropical and subtropical sea, while a few wander into northern and southern temperate regions. Although such may be the case, however, most of them probably live within 100 or 200 miles of land, and the geographical distribution of some, at least, is not much less restricted than that of ordinary shore fishes. "About 65 species" have been described, and of those about 20 have been found in American seas, the others, of course, being limited to that extent at least. Five of the American species have not been found elsewhere, *Cypselurus xenopterus*, *C. californicus*, and *C. callopterus* being known only from

the Pacific coast of America, and *C. gibbifrons* and *C. cyanopterus* from the Atlantic. The others enjoy a wide range and most are found both in the Atlantic and Pacific.

There is a notable uniformity in size for so large a group, the extremes for full-grown of different species being near 8 inches at one extremity and 18 at the other. About a foot is near the average and a foot and a half appears to be the usual length of the full-grown Californian flying fish (*Cypselurus californicus*), and sometimes at least attained by several others.

All are gregarious and keep quite close together in large—sometimes very large—schools. They often swim at or very near the surface of the water, with the pectoral and ventral fins pressed close to the body, or at least not far divergent from the sides and below, and are propelled "by rapid, long, sweeping strokes of the tail and posterior half of the body." But every now and then the pectoral fin on one side is slowly expanded to its full extent for the purpose, it appears, of simply stretching them for exercise, as they swim on without turning with the fin open. The effect of this expansion appeared to Hugh Smith "exceedingly striking and pretty, the fin looking like silver, and when several of the fish were in company the flash caused by a fin being opened, now here, now there, now on one side of a fish, and then on the other, heightened the effect considerably. It was curious to note, when the expanding fin was closed, how completely it disappeared, altering the appearance of the fish entirely." Sometimes in sport, sometimes to escape pursuing enemies, with increased vigorous movements of the tail, they spring out of the water, immediately spread their pectoral and ventral fins, and start an aerial progress known as flight.

The so-called flight of the flying fishes has been the subject of much heated controversy. The coolest and most scientific treatment of the question has been made by Karl Möbius, and most of the best equipped recent investigators have come to the same or similar conclusions as he did. Flying fishes do not fly any more than flying squirrels, flying opossums, flying lemurs, flying lizards, or flying frogs; they do not fly like birds or bats or most insects. The answer to the question, "Do flying fishes fly?" will therefore depend on what is called flight. If flight is the act or result of a volitional series of beats of the wings, as in birds, then fishes do not fly; if the word be extended to cover the use of quasi-wings for inactive sustentation of the body or as parachutes, as in flying squirrels or flying opossums, then flying fishes may fly.

Möbius (1878, 1885) contended that "Flying fish *are incapable of flying* [the italics are his] for the simple reason that the muscles of their pectoral fins are not large enough to bear the weight of their body aloft in the air. The pectoral muscles of birds depressing their

wings weigh, on an average, one-sixth of the total weight of the body, the pectoral muscles of bats one-thirteenth, the muscles of the pectoral fins of flying fish only one thirty-second. The impulse to which flying fish owe their long shooting passage through the air is delivered while they are still in the water by the powerful masses of muscle on both sides of their body, which are of much greater breadth than in the case of the herring or any other fish of their own size."

The movement of the pectoral fins, described generally as flickering, vibrating, or flapping, "is only a vibration of their elastic membrane, and is to be referred to the same laws as those which govern the flapping of a tight-set sail when a ship under a stiff breeze is driving close to the wind. The flapping or vibration at once springs up whenever the sail gets parallel to the wind.

"The more rapidly a flying fish darts out of the water the greater is the momentum with which the air presses on the outspread pectoral fins. Should, now, the atmospheric pressure induce these fins into a horizontal position parallel to the wind their vibration is a necessary result. Let the outspread pectoral fins of a dead flying fish be held horizontally before the opening of a pair of bellows and the fins will be seen to vibrate as soon as the current of air passes under them."

Such are the conclusions enunciated by Möbius in a special memoir (in German) on the movements of flying fish through the air (1878) as epitomized in 1885. These, however, were vigorously objected to by C. O. Whitman (1880), who urged, "Admitting that in form, size, length, and structure the pectoral fins of *Exocætus* are less well adapted to flight than the wings of most birds, there is still ample room to believe, on anatomical and physiological grounds alone, that they are capable of executing true flight."

Opposed to this view are the expressed opinions of many distinguished traveler-naturalists. Moseley, who circumnavigated the globe as naturalist of the great Challenger Expedition, expressly declares that he had "never seen any species of *Exocætus* flap its wings at all during flight. These fish merely make a bound from the water and skim, supported by their extended fins, the tips of which meanwhile quiver in the air occasionally from the action of air currents against them, and sometimes from the shifting a little of their inclination by the fish." Jordan and Evermann (1896), who had many opportunities for observation "under most favorable conditions," were convinced that "no force is acquired while the fish is in the air. On rising from the water the movements of the tail are continued until the whole body is out of the water. While the tail is in motion, the pectorals seem to be in a state of rapid vibration, but this is apparent only, due to the resistance of the air to the motions of the animal. While the tail is in the water the ventrals are folded. When the action of the tail ceases, the pectorals and ventrals are

spread and held at rest. They are not used as wings, but act rather as parachutes to hold the body in the air." Boulenger, the best-informed ichthyologist of Europe, voices the general verdict in the apt declaration (1904) that "nearly all" the family "are in the habit of making great leaps out of the water," and this tendency culminates "in the flying fish (*Exocœtus*), which skip or sail through the air in a manner the explanation of which has given rise to much controversy. According to the latest evidence, the sole source of motive power is the action of the strong tail while in the water. No force is acquired while the fish is in the air. The pectorals are not used as wings, but as parachutes."

The contention that flying fishes have the power to materially modify their course in midair is generally thought by qualified ichthyologists to be not corroborated by their structure or by exact observation. Louis Agassiz (1868), however, was "confident not only that they change the direction of their flight, but that they raise or lower their line of movement repeatedly without returning to the water."

They must have leverage to work from, and after leaving water they must go as their final impulse directs or as the wind determines. Even those who contend that they can direct their course may admit that "when in mid flight" they can not "suddenly divert their course." Mathew (1873) observed one which "emerged from the sea within 10 yards of the ship and flew directly toward her, coming so violently into contact with the ship's side that it fell stunned, and floated astern on the surface of the sea with its pectoral fins rigidly expanded." Possibly they may be able sometimes to flex the tail or fold one fin in the air and thus change the course to some degree.

The extent of flight at a single stretch naturally varies with circumstances. The best estimate has been that an ordinary flight may extend from 30 to 50 yards in less than twenty seconds, but this may be reenforced by dipping in the sea and obtaining a new basis for propulsion. Mathew (1873) thought that "200 yards would be an unusually long flight," but had "occasionally seen individuals go at least 100 yards farther," and believed "if hard pressed they could even exceed that." Mr. F. A. Lucas writes to me: "I have seen this fish come aboard from leeward and have seen them fly very much more than 200 yards. I have seen them come up to the vessel's bow, but they did not alter their course; simply folded their wings and dropped back again." He explained that "the distance a fish travels through the air, after ricocheting from a wave top, before it again touches the sea is often much greater than its original flight, and besides gaining fresh impetus from this contact they also remoisten their gills and refresh themselves." Jordan and Evermann estimated that "they will 'fly' a distance of from a few rods to more

than an eighth of a mile, rarely rising more than 3 or 4 feet. * * * When the fish begins to fall, the tail touches the water, when its motion again begins, and with it the apparent motion of the pectorals. It is thus enabled to resume its flight, which it finishes with a splash. When in the air it resembles a large dragon fly. The motion is very swift, at first in a straight line, but later deflected into a curve. The motion has no relation to the direction of the wing. When a vessel is passing through a school of these fishes, they spring up before it as grasshoppers in a meadow."

When a flying fish falls on the deck of a vessel it may spasmodically and very rapidly move its pectorals upward and downward, and such a movement may be made while the fish is "on the wing" and give the appearance of "vibration," so often claimed to be observed. This action doubtless adds something to the force of the leap from the water, but it is by no means actual flight.

It has been claimed that flying fishes are not often to be seen in periods of calm and a smooth sea; it is when the winds blow strong and the waves roll high that most of them make their appearance. "It is easy to understand how the action of the wind combines favorably or otherwise with their flight." "As any air in strong motion, when it impinges against obstacles (a ship's side or waves) rises, it raises also the fish, so that this flies over the wave or may come on board the ship. In short, as Professor Möbius proves in detail, all the phenomena observed may be fully explained by the combined action of the oblique projection forward and the wind." "Directly against the wind they commonly fly farther than with the wind, or when their course and the direction of the wind form an angle together. Most *Exocœti* which fly against the wind or with the wind continue, during their whole course of flight, in the direction in which they come out of the water. Winds coming laterally upon the original course of the *Exocœti* deflect these into their direction."

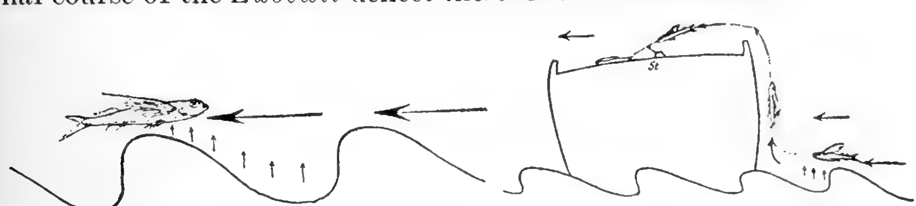

Fig. 2.—Showing how the flight of the fish is influenced by wind current.

The qualification that the fishes are "not often to be seen in periods of calm" of course implies that they may be sometimes. Kneeland (1870) specifically asserts that he saw them rise "out of a perfectly smooth sea." Whitman (1880), a much more reliable observer, also had "often seen great numbers of these fish when the air was almost motionless—so still that not a ripple could be discovered on the glossy surface of the water"—and it even seemed to him "that they were

not much, if at all, less numerous on such occasions than when there was a moderate wind."

Flying fishes rarely fall on board of a ship during the light of day, but passengers on the old sailing vessels were frequently told in the morning that fishes had been caught on deck during the night and would serve as part of their breakfast. According to Möbius, "they mostly fall upon ships which lie not higher than 2 to 3 meters above water, and when these are sailing on a wind (the wind coming obliquely from beyond) or with half a wind (the wind coming at right angles against the ship) and are sailing rapidly. Flying fish never come on board from the lee side, but always and only from the weather side." All those "which withdraw from ships fly, during their whole course through the air, near the surface of the water."

Collingwood (1868) had "known them fly into a cabin through the open port, attracted by a light burning within." The fact of entry into the cabin need not be questioned; the inference that it was deliberate is a nonsequitur.

The flight of a flying fish is never brought to an easy and graceful conclusion like that of a bird, but ends in a fall and with a splash.

Those flying fishes which keep near the coasts and resort to shallow water may occasionally, at least, seek and rest on the bottom, as Goode (1876) has recorded that *Cypselurus exsiliens* did. In Bermuda he received a small living fish which he kept alive "for some hours." Its "favorite position was on the bottom of the dish, where it would remain with its pectorals and ventrals expanded, looking very like a large butterfly sunning itself on a flower. When disturbed it would fold its fins close to the sides of its body and swim about with great velocity by rapid, long, sweeping strokes of the tail and posterior half of the body. The extent to which it flexed its body was quite remarkable, almost reminding one of the motions of a shark. When much excited it would rise into the air with a sudden spring, its pectorals expanded, seeming to have no difficulty in leaving the water in a space less than a foot in diameter."

Flight, indeed, must be considered as only an occasional exercise of flying fishes, and the normal condition must be one of rest or quiescence alternating with natation, which may frequently be extended into emergence from the water or flight. For economical purposes the fishes are looked for in the water and in the water are caught, as will be seen by the notices respecting their capture given in subsequent paragraphs of this article.

II.

The food of the flying fishes consists of such animal organisms as occur in the seas which they frequent. They are numerous crustaceans, some mollusks, such as Pteropods and Janthinids, and various

small fishes. The fishes are, in fact, almost omnivorous, as may be understood from the means of capture used by professional fishermen and anglers.

III.

Their procreative characteristics are very little known. Accounts are contradictory, but it may be because there is a difference in this respect between different species or even different shoals. Mathew (1873) was "inclined to fancy" that they spawned "in mid-ocean," for he had "seen them not an inch long more than 1,000 miles from the nearest land, and these minute specimens when in the air bear a strong resemblance to locusts on the wing." Many young have been observed and collected by others in mid-ocean. There is, in fact, little if any, doubt that some do spawn far from land. Howard Saunders, an excellent ornithologist, however, found large shoals about rocks and inferred that they were there to spawn (1874). "At the Chincha Islands, on the coast of Peru," Saunders observed numbers of an unidentified species make "their appearance about the last week in March, and the water round the rocks was alive with them, the numerous fissures and crevices seeming all too few for their requirements. Looking down through the clear water," he "could see a moving mass struggling for places, and, respecting a long narrow rift, one of the sailors remarked that it was 'just like the pit on boxing night.'" As many as were wanted "could be taken with the hand from the fissures in the rocks." At the time Saunders "never noticed these flying fish 'on the wing,'" and inferred that "doubtless they were too heavy." [a]

The author of an article on "flying fish catching in Barbados," contributed to Chambers's Journal (1894), claims that there is "no doubt that they deposit their ova in the massive banks of 'Sargasso [=Sargassum] bacciferum,' or Gulf-weed, which is met with in such vast quantities as to impede a vessel's progress through it. Through the pleasant groves and avenues of these floating forests the young fry in millions disport in comparative security." The author claims also to have "often amused" himself "by catching the young fry thrown up with piles of Gulf-weed on the beach and seen masses of the spawn, like huge bunches of white currants, entangled among its close-knit fronds." These bunches were probably from the Antennarioid mouse-fish (*Pterophryne histrio*), and the young fry may have been misidentified.

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[a] Mr. F. A. Lucas writes to me that "in regard to the flying fish, *Exocoetus*, my experience at the Chincha Islands was similar to that of Mr. Saunders except that I did not find them so abundant. I saw them in the water and caught some with the grains, but never saw one fly there."

Whatever may be the facts respecting the places selected for spawning, the eggs of flying fishes are undoubtedly like those of their relatives. Some eggs obtained near Naples in June and July, 1894, were identified as those of an exocoetine, and described by F. Raffaele. They were found attached to floating bodies (straws that had been used for packing fruit) from which they hung like pigmy grapes. They had characteristic filaments, not very unlike those of *Scomberesox*.

The early post-embryonic stages are unknown, but undoubtedly it will be found that the pectoral fins at first are short and that their large size is acquired some time after birth.

IV.

Flying fishes are beset by enemies in the form of large pelagic fishes, such as dolphins, tunnies, bonitos, and albicores, as well as sharks and porpoises. In order to help them escape, the development of the power to leave the water has resulted, and most of the near relatives of the flying fishes which could not acquire the power have long since ceased to live, for the nearest living relatives belong to other groups—the Sauries and Half-beaks. The pursuing fishes are as swift and active in the water as the flying fishes, and even escape from the water serves often only to delay capture, for the pursuing fish may catch one as it falls from the air. The history of a shoal of flying fishes pursued by one of dolphins would be an interesting as well as tragic one. Is pursuit ever continued till the shoal is exterminated or a few escape through their insignificance in the vast waste of water?

There is another phase of danger, attributed in many a popular work, from which the flying fish are practically—that is, generally—exempt. The danger is often represented as twofold, a piscine Charybdis and an avine Scylla. But danger from birds in the air is almost nothing.

It must not be supposed, because a shoal of flying fishes is observed at sea with many in the air at one time, that pursuers are necessarily in the rear. Notwithstanding the statements of some travelers, the fishes may be unmolested, and their aerial excursions may be merely the manifestation of exuberance of spirit and in obedience to an instinct which impels not only them but all their distant relations—the sauries, halfbeaks, and garfishes—to leap from the water. Possibly a school may enjoy a lifetime free from molestation.

F. Mathew, "during long voyages in the Atlantic and Pacific oceans," had many "opportunities of closely observing the habits of flying fish," but he had never "seen a bird of any description attempt to seize them while in the air," nor was he "acquainted with anyone who has witnessed such a thing." He knew of "no bird that could

manage to catch them. The various species of albatross, petrels, gulls, skuas, and shearwaters are either too slow on the wing or too small." While it is not impossible that birds may occasionally pursue fishes, such attacks must be quite exceptional and not habitual, as popular accounts would lead the reader to suppose. Such stories have been repudiated also by Saunders (1874), Pascoe (1881), and the Earl of Pembroke.

Nevertheless, flying fishes, under some circumstances, can be caught by birds and are caught in numbers. Collingwood, in his "Rambles of a Naturalist" (1868), records a notable case. "Pratas Island" is a coral islet of the China Sea (latitude 20° 42′ north, longitude 116° 43′ east), "about a mile and a half long and half a mile wide," frequented by numerous gannets and, on examining the food vomited by disturbed birds, Collingwood "found it to consist invariably of flying fish, generally of a large size, and usually but slightly digested. There were sometimes six or seven of these fish, in other cases only three or four, in two or three cases a squid or two intermixed with them." Yet "not a single fish was observed on the wing" near the islet. The ingested fishes "were probably taken in the water by the birds."

V.

Flying fishes are of considerable gastronomic importance and are regarded by most of those who have tried them as very savory and surpassed by few others. Perhaps the best known to epicures are the *Cypselurus speculiger* (long known as the *Exocœtus volitans*) and the *Cypselurus californicus*. The palatability of the former was appreciated at Barbados by the writer, and Jordan and Everman have declared the latter to be "an excellent food fish, sometimes taken by the thousand off Santa Barbara." On account of their mode of occurrence, however, regular fisheries are entirely exceptional.

One region, the island of Barbados, is quite celebrated on account of the numbers of a species of flying fish just mentioned (*Cypselurus speculiger*) that occur in the vicinity. It is "so abundant in some seasons of the year," says R. H. Schomburgk (1848), "that they constitute an important article of food, and during the season a large number of small boats are occupied in fishing." "Such large numbers are occasionally caught that they meet with no sale and are thrown away or used as manure." They form a staple in the way of fish for the island and every visitor during the proper season is advised to try the flying fish and, heeding, does not repent. "The succulent delicacy of the fish is certainly a thing to remember." So records a writer in Chambers's Journal (1894).

The fishing grounds are "little more than 10 or 12 miles from

home," some not more than 5. "There are about 200 boats engaged in the fishery. Nowise notable for grace of form or elegance of rig, they are substantial, undecked vessels of from 5 to 15 tons capacity, built in the roughest manner, and furnished in the most primitive way. The motive power is a gaff mainsail and jib and a couple of sweeps for calms. * * * The fleet leaves the 'canash' (harbor) before daybreak, each skipper taking his own bearings and working for the spot which he thinks will furnish the best results. * * * The tackle used is of the simplest kind. A wooden hoop 3 feet in diameter, to which is attached a shallow net with inch meshes; a bucketful of—well, not to put too fine a point on it—stinking fish; a few good lines and hooks, and a set of grains, form the complete layout. * * * As soon as the boat is hove to and her way stopped, the usual exuberant spirits and hilarious laughter are put and kept under strong restraint, for a single sound will often scare away all fish in the vicinity and no more be seen that day. The fisherman leans far over the boat's side, holding the hoop diagonally in one hand. The other hand, holding one of the malodorous fish before mentioned, is dipped into the sea, and the bait squeezed into minute fragments. This answers a double purpose; it attracts the fish, and the exuding oil forms a 'sleep' or glassy surface all around, through which one can see to a great depth. Presently sundry black specks appear far down; they grow larger and more numerous, and the motionless black man hanging over the gunwale scarcely breathes. As soon as a sufficient number are gathered he gently sweeps the net downward and toward the boat withal, bringing it up to the surface by drawing it up against the side. Often it will contain as many fish as a man can lift; but so quietly and swiftly is the operation performed that the school is not startled, and it very often happens that a boat is filled (that is, 7,000 or 8,000 fish) from one school. More frequently, however, the slightest noise, a passing shadow, will alarm the school; there is a flash of silvery light, and the water is clear, not a speck to be seen. Sometimes the fleet will return with not 1,000 fish among them, when prices will range very high until next day, when, with 50 or 60 boats bringing 5,000 or 6,000 each, a penny will purchase a dozen."

This mode of catching flying fishes has been in vogue in Barbados for a couple centuries. G. Hughes (1750) observed that "when full grown and in perfection" they "will neither fly out of [man's] way, as they do from the dolphin, nor will they dive into the deep, but suffer themselves to be taken up with the hand or with a small hoop net, which is the common and most expeditious way of taking them."

The mode of fishing thus described is designated by the Barbadians as "driving" and is one of the three special ways of taking the

three principal market fishes of Barbados, the others being "snappering" for the snapper (*Ocyurus chrysurus*) and "brimming" for the brim or bream (*Etelis oculatus*). According to a report of the West India royal commission of 1897, "the flying-fish season extends over about seven months—from December to July. After July" the fishes "become poor in size and quality and develop what are known to the fishermen as 'feathers,' but are probably some kind of parasite," probably the crustacean *Penella*, "which infests their bodies and renders them unfit for food."

The royal commission of 1897 reported that "an average catch may be put down at 1,000 to 1,500 fish, but it not unfrequently happens that the take reaches as high a figure as 5,000. The heaviest catches are made in April and May. At such times the supply sometimes exceeds the demand, when great quantities are wasted or merely used as manure. The average quantity landed monthly at Bridgetown fish market in a good season is 390,000, and the average price obtained may be put down at the rate of 150 fish for one dollar. The owner of a boat takes a third of the whole catch; the remaining two-thirds is divided among the hands. The building and fitting of a flying fish boat is about $150, and the annual outlay in repairs, etc., amounts to about $30."

Flying fishes might be regarded as unlikely subjects for fly angling, but Francis Smith (1875) experimented with gratification to himself. "The monotony of a sea cruise was pleasantly broken on the 25th of January by an occurrence so unusual as to excite the wonder of the oldest sailors. Off the coast of Peru a large shoal of flying fish appeared and afforded excellent sport during the afternoon. A variety of baits were employed in their capture—bits of red bunting, small spoon baits, and artificial minnows and flies—the most taking being a large red fly and a small gilt minnow, but all the baits mentioned caught some. In following the minnow through the water, the fish would open both pectoral fins and poise themselves for a rush at it; spreading the wings also had the effect of checking their progress if their suspicions were aroused by a near inspection of the bait. When hooked they proved a very game fish, taking out several yards of line in their first rush, and often taking a flight in the air, line and all."

VI.

The many species of the exocœtine flying fishes naturally appear under many modifications of varying significance and have been segregated in six genera. Four may be diagnosed here.

Most of them have the snout short and the lower jaw more or less obtuse, the pectorals elongate and extensible nearly or quite to the caudal, the ventrals inserted behind the middle of body and extensible

beyond the first rays of anal; further, the ventrals are acutely elongated at the third ray and the first two short and compressed. The species so distinguished are combined in the genus *Cypselurus*.

A few species agreeing in most respects with the *Cypseluri* differ in the insertion of the ventral fins in advance of the middle of the body as well as in their brevity; the fins are also truncate or emarginate and very short, not extending to the anus; the pectorals are moderately elongate. They constitute the genus *Exocœtus* and the only species of the entire group (*E. volitans*) known to Linnæus is one.

A few other species agreeing fundamentally with the *Exocœti* have the ventrals submedian and rather short but angulated by the extension of the third ray; the pectorals are moderately long; furthermore, the roof of the mouth is more dentigerous, the vomer, palatines, and pterygoids being armed with teeth. These have been set apart in a genus called *Parexocœtus*, the type of which is the *P. mento* of the Indian and Sunda-Moluccan seas. An American species is the *T. hillianus* of the Caribbean Sea.

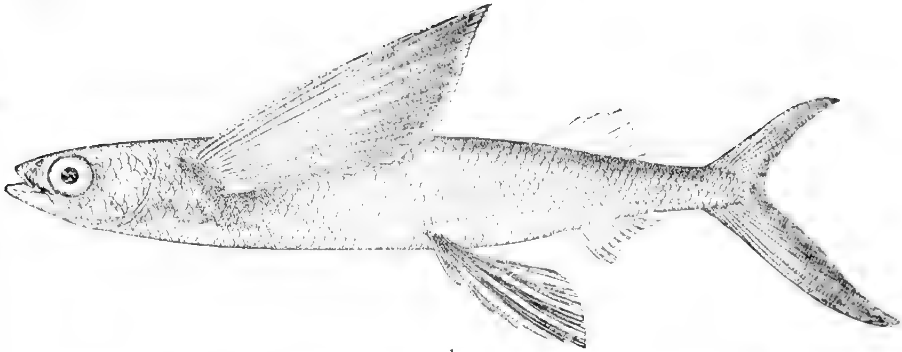
One species is separated from all others by the pike-like head, the snout being longer than the postorbital region and the lower jaw elongated, projecting in front and with a flat, triangular area; the pectorals are moderately elongated, the ventrals rather short and rounded behind. The single species is the *Fodiator acutus* of the tropical American seas.

The differences thus indicated are coincident with others.

II. The Dactylopterids, or Flying Gurnards.

I.

The Dactylopterids, otherwise known as Flying Gurnards or Flying Gurnets, differ radically and in innumerable characters from the true Gurnards, and vastly more from the Exocœtoid flying fishes, but a few external ones will suffice to give an idea of the family. The elongated body is somewhat swollen upward under the first dorsal, and covered with hard-keeled scales; the head is oblong and parallelopiped, and the suprascapular bones form an integral part of the skull, and extend far back as flat spiniform processes on each side of the dorsal fin; the preoperculum of each side is armed at its angle with a long horizontal spine reaching backward under the pectoral; the jaws have granular teeth; the branchial apertures are contracted; the dorsal fins short, as is also the anal; the pectorals divided into two parts, a small anterior and a very large posterior, which spread out sideways; the ventrals imperfect and not far apart. The pectorals are set upon osseous bases (actinosts) differentiated for the two parts.



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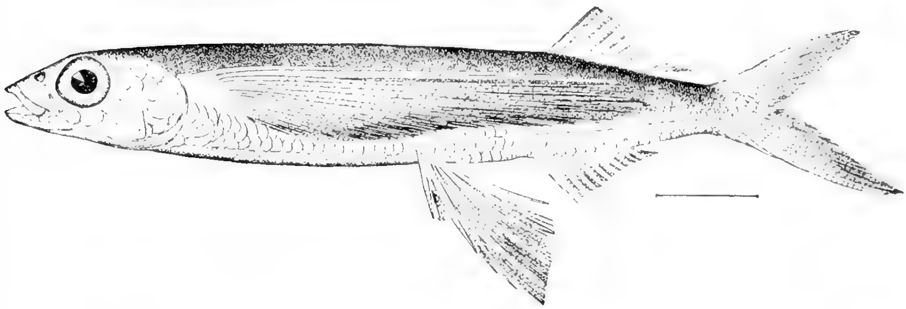

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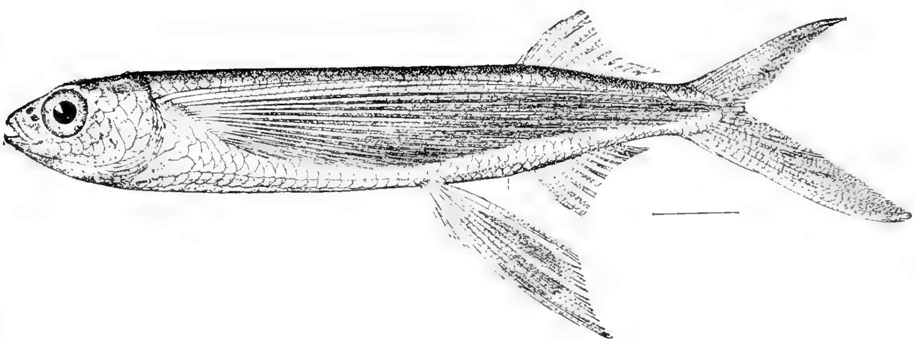

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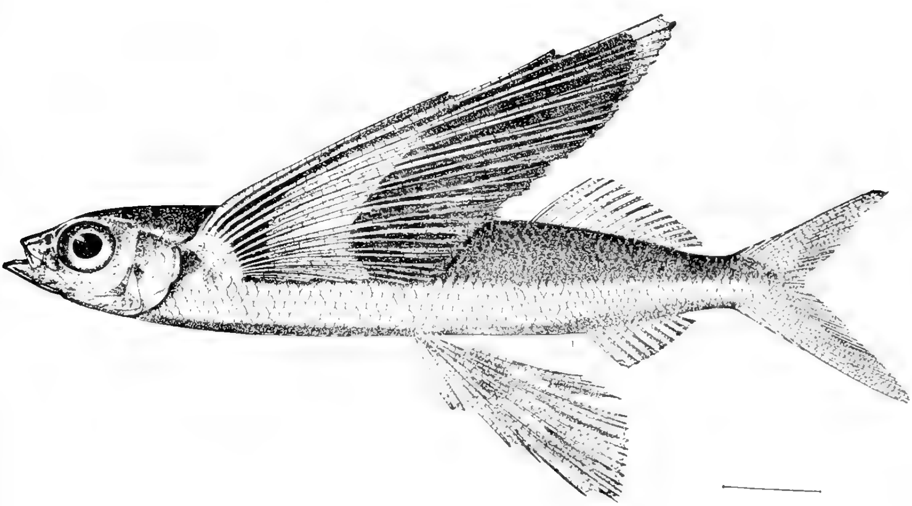
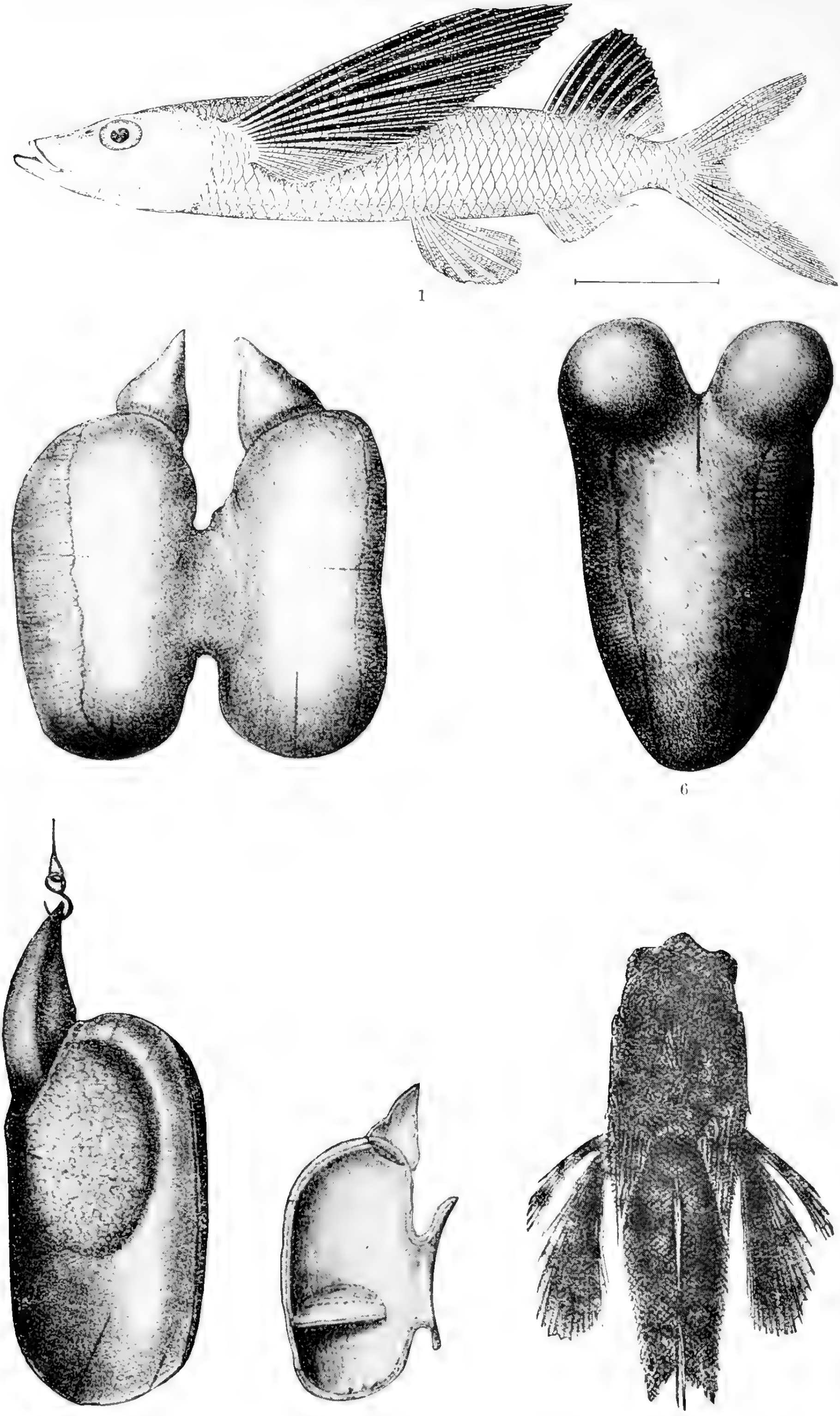


4

1, CYPSELURUS CALIFORNICUS; 2, CYPSELURUS EXSILIENS; 3, CYPSELURUS RONDELETII; 4, CYPSELURUS SPECULIGER.



FODIATOR ACUTUS, DACTYLOPTERUS VOLITANS, AND AIR BLADDERS.

1, *Fodiator acutus*; 2, *Dactylopterus volitans*, in youngest post-cephalacanthus stage, magnified twice; 3, air bladder of *Dactylopterus*, seen from below, with the lateral intrinsic muscles; 4, air bladder (right lobe) with insertion of extrinsic muscle and pyramidal appendage held by hook; 5, air bladder (right lobe) interior with the incomplete diaphragm; 6, *Trigla cuculus*: air bladder, from below, to contrast with that of *Dactylopterus*.

As almost every external feature is characteristic, so are many internal parts. In connection with the longitudinal arch or convexity of the back, so different from the straightness of that of the Gurnards, a very remarkable deviation of the air bladder from normal relations is noteworthy; the dorsal curvature, indeed, is a coordinate of an otherwise unexampled position of the bladder.

The air, or swimming, bladder is unique in character, as Calderwood states, in that "it is not situated below, but [mostly] above, the vertebral column, not forming part of the abdominal contents, but situated dorsally in a special cavity [recess] of its own. When the abdominal cavity is opened ventrally, and the viscera removed, only the ventral surface of the bladder is seen, forming part of the dorsal boundary of the cavity. Seen from this point of view, it is formed of a broad central portion, white and tendinous, and of two lateral portions strongly muscular." The physiological significance of this comes into view when we consider one of the habits or aptitudes of the fish.

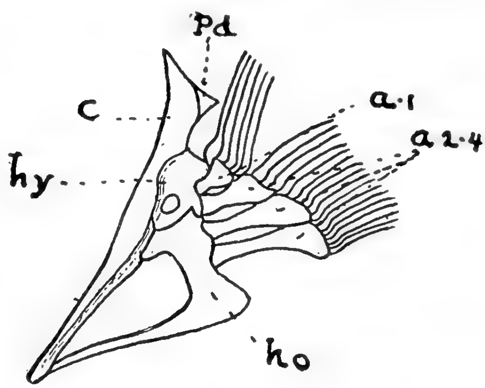


FIG. 2.—*Dactylopterus volitans:* Shoulder girdle. (After Boulenger.)

The structure and position of the air-bladder are adapted for keeping the Dactylopterid with back upward in the air in spite of the form of the body and its relation to the vertebral axis. "The bladder, being prevented from expanding when the pressure from the surrounding water is suddenly removed, the high dorsal position of the secondary portion becomes of the greatest possible advantage." It helps the fish to emerge from the water and maintain its equilibrium in the air.

Such are the most characteristic features of the Dactylopterids common to all the members of the family. The species are few—about half a dozen—and closely related to each other, all being strictly congeneric.

It might naturally be supposed that fishes so specialized in form, so peculiar in appearance, and so remarkable for the development of their pectoral fins and their unusual functions, would have received distinctive English names, but such is not the case. Flying gurnards or flying gurnets are the general names given in most works, but they are mere book names and not of the common people; further, the names are deceptive and have often misled, for the fishes are not very closely related to the true gurnards or gurnets, although more so than to any other fishes. Bat-fish is a designation for the common

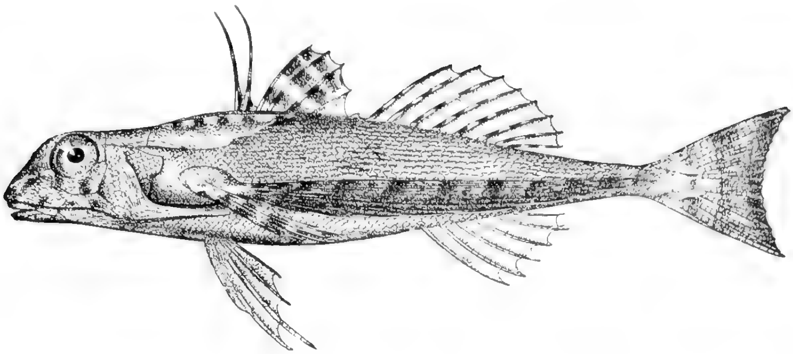
Dactylopterid of the Atlantic in Barbados, and Cook (or Cooke) is another peculiar to Jamaica. The former name, however, is better known in connection with the strange pediculate fish, *Malthe vespertilio*, and the latter (Cook) is the specific term of a wrasse in England and of species of Holocentrids (*Holocentrus* and *Myripristis*) in Barbados.

The most common species, or at least the most generally known, and the only one certainly ascertained to be an inhabitant of the Atlantic Ocean, is the *Dactylopterus volitans*. The best and fullest account of its habits has been given by R. Schmidtlein (1879), who had good opportunities to observe it in the tanks of the zoological station at Naples. A translation from the German of the greater part of his observations is interwoven into the following account.

The appearance of the living fishes, as it appeared to Schmidtlein, is thus described:

The flying gurnard (*Dactylopterus volitans*) occurs about Naples in great numbers, principally in the autumn and until the late winter, and approaches very close to the gurnards as regards its habits. Its appearance is very peculiar and suggestive of its mode of life. The bony cap which, like a stiff mask, incloses the skull, gives to it a peculiar physiognomy from which, however, the bull-like feature of the gurnards (*Trigla*) is absent, because the eyes are placed laterally and the snout declines abruptly from the frontal. The result is a well-formed head of the right proportion to the size of the body, and from which the large, round eyes with red irises are moved in a jerky manner and look out with a wondering expression. To this armored part of the body is joined the nearly conical trunk, covered with hard scales and with a complete equipment of fins. First come the pectorals which are modified into large organs for flying and provided in their anterior portion with short individually movable rays which, however, are connected by a membrane. Behind the throat are the ventrals which have been advanced forward; they are for the most part folded and directed downward. The dorsals are delicate and provided with a glass-like transparent membrane.

The coloring of the fish appears at a distance and superficially as a mixture of dark tints, but is found to contain, on closer examination, a great quantity of many-colored markings. The back is colored a beautiful brown, with dark spots and bands. The sides, as far as the middle of the belly, are pale rose, with silvery reflections, and the outspread wings show in the center rows of black and light eye-like spots, which recall the coloring of tropical butterflies by their markings and gay tints, together with the magnificent blue with which they are hemmed in. This beautiful sight may be espe-



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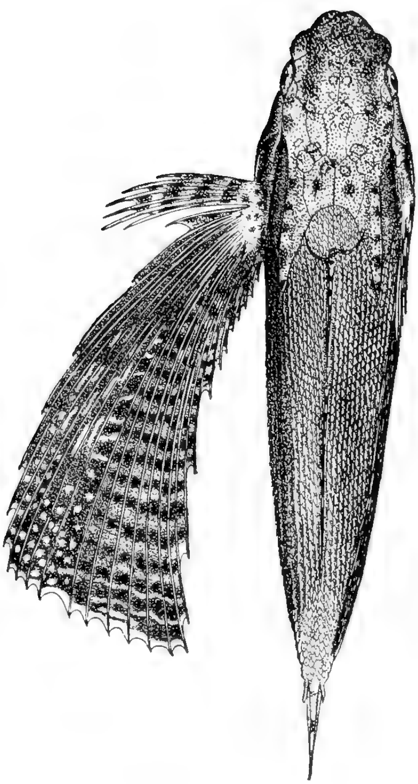

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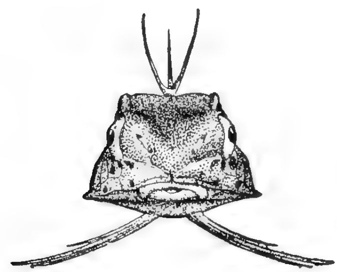

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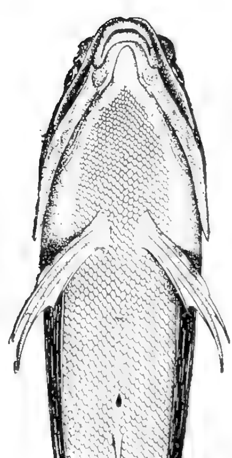
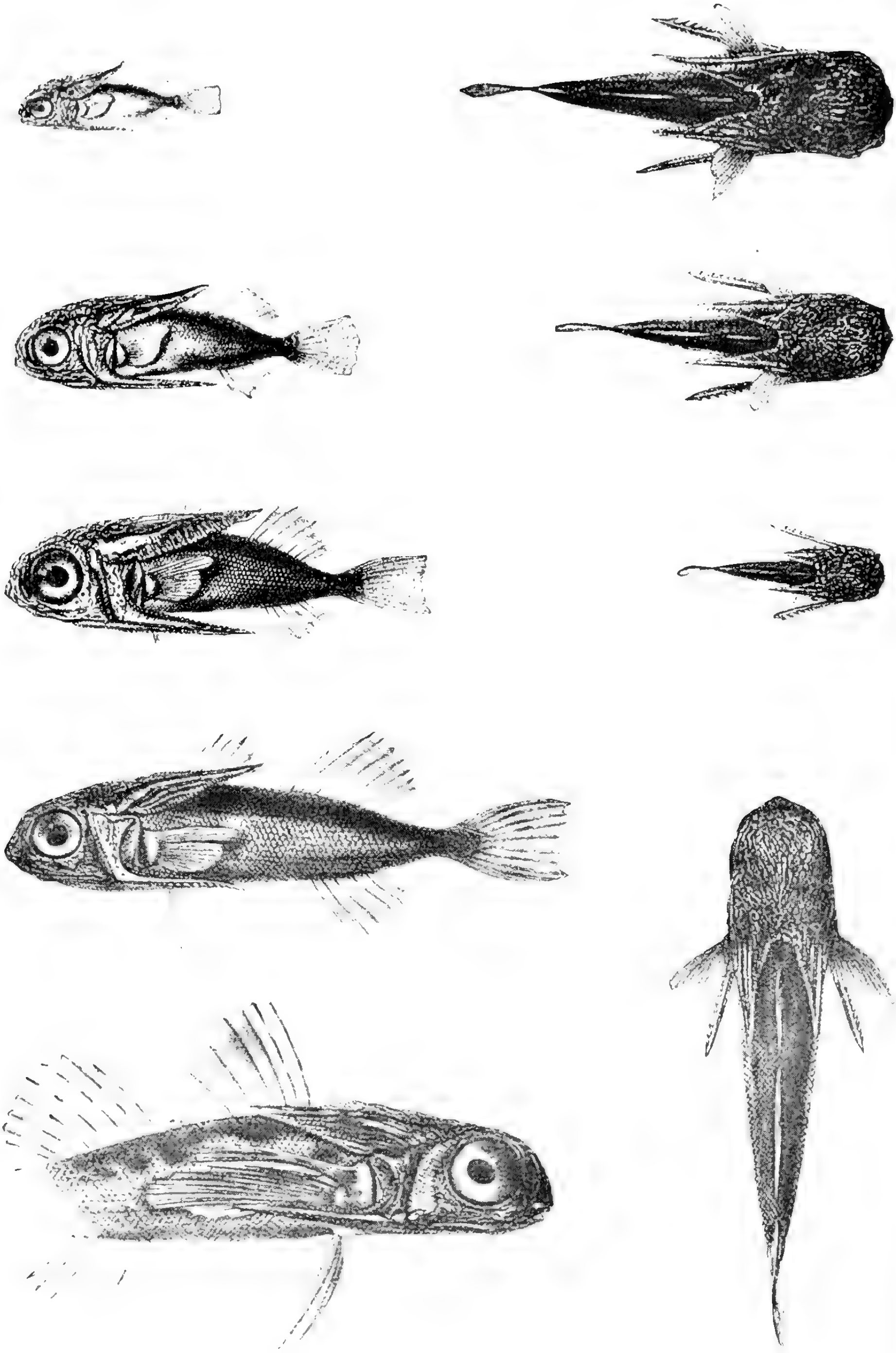


3

DACTYLOPTERUS VOLITANS.

1, From the side, with expanded wings, seen edgewise; 2, from above, with left wing partly expanded; 3, from below, to show isthmus, narrow interpectoral area, and side; 4, face.



DACTYLOPTERUS VOLITANS—DIFFERENT STAGES OF GROWTH. (AFTER LÜTKEN.)

cially enjoyed when looking at the fishes from above in the sunlight or in the broad daylight, while inducing them to unfold their wings by holding a stick close to them. Then golden green specks appear all over the body; at every motion the fins play in all colors in different places, like the wings of the butterfly known as the purple emperor, and also the gay mingling of beautifully distributed tints on head and back contribute to the splendor of the brilliant creature. Besides, *Dactylopterus* possesses the faculty of changing its colors to light or dark. This is particularly fortunate for the young ones, where the bottom is similarly colored, as, because of their small size, they are more exposed to the attacks of enemies. It has also been observed that the young flying gurnards far more commonly stay on the bottom of the basin than the larger fishes, and here harmonize splendidly with the sand, especially where it is mixed with multicolored gravel. Furthermore, the coloring of such specimens is also less pronounced and the markings are darker, more monotonous, and frequently indistinct. At dusk the fishes are often scarcely visible.

The adult Dactylopterids like to stay on the bottom of their basins, where they stand and walk about on the ends of their downward-turned ventrals like the Gurnards do on their "legs," while they wag their dorsal fin and tail and scratch in the sand with the short anterior portion of the pectoral to look for food. They are gregarious and swim about in a body, even when in company with other fishes. They show great resemblance to the Gurnards in their movements and in the use of their fins, and what has been said with regard to the Gurnards in this respect is applicable to the Dactylopterids, with the exception that the latter swim somewhat more slowly and leisurely, and possess a stronger inclination for flying than the former. Their power of flying may not be far behind that of the Exocœtines.

But although at first sight so well adapted for semiaerial life, the Dactylopterids are nevertheless essentially bottom fishes, or seek rest on some surface. Sir John Richardson long ago (1865) noted that "in the clear waters of the Boca Tigris, off Trinidad, great sculls of these fish may be seen near the bottom, perpetually fluttering their large wing-like pectorals." Of course, in mid-ocean some other kind of resting place must be secured and there the beds of sargasso weed furnish suitable resorts. But near land they resort to the bottom at considerable depths, and in temperate regions, on the approach of winter, retreat to still greater depths to secure a warmer and more equable temperature.

The power of flight has been attributed to Dactylopterids by most authors, and is there not a fine colored plate illustrating a school of them in mid-air in a very popular work on natural history (Brehm's

Thierleben)? Against this power other authors have pronounced and denied the fishes any aptitude for aerial progression. On the one hand, Signor Le Bianco, of the zoological station of Naples, informed W. L. Calderwood (1889) that "it is met with in the bay at a depth of from 20 to 60 meters, say 10 to 30 fathoms, but is never seen on the surface." (Le Bianco, in an article of his own (1888) had indicated it as scarcely pelagic (raramente pelagico). On the other hand, some reliable men and good naturalists have testified to their ability to emerge from the water and progress for short distances through the air. Neglecting all observations recorded more than half a century ago, comparatively recent notices confirm old statements, to some extent at least.

Richardson, the best informed ichthyologist of the middle of the last century, also especially testified to their aerial excursions "They are able to rise from the water and fly through the air like the Exocoeti or flying fishes already mentioned. With such force does the *Dactylopterus* pursue its flight that it will spring upon the deck of a ship of war, and it has been known to strike a sailor on the forehead and knock him down."

Moseley, the naturalist of the great Challenger Expedition, attested that "whilst out in a boat collecting animals amongst the gulf weed" he saw Dactylopterids around him and "watched these little flying fish fly along before the boat at a height of about a foot above the water for distances of 15 or 20 yards," and he "chased them and caught one or two with a hand net amongst the weed."

Moseley believed that the Dactylopterid had a somewhat different flight from the Exocoetids. He had "never seen any species of *Exocoetus* flap its wings at all during its flight. These fish merely make a bound from the water," but he believed he could "not be mistaken" in the conviction that he had "distinctly seen species of flying gurnets move their wings rapidly during their flight. I noticed," says he, "the phenomenon especially in the case of a small species of *Dactylopterus* with beautifully colored wings, which inhabits the Sargasso Sea. Whilst out in a boat collecting animals amongst the Gulf weed, these small flying gurnets were constantly startled by the boat and flew away before it, and as they did so appeared to me to buzz their wings very rapidly. Their mode of flight seemed to me to be closely similar to that of many forms of grasshoppers, which can not fly for any great distance, but raise themselves from the ground with a spring and, eking out their momentum as much as they can by buzzing their wings, fall to the ground after a short flight.

"Doctor Möbius, who similarly watched the flight of a species of flying gurnards, maintains that neither form of flying fish flap their wings at all during flight. I no not consider the question as

yet set at rest. Of course no flying fish can raise themselves in the air by means of their wings alone."

Schmidtlein believed that their power of flying was probably not far behind that of the Exocoetids, so far as the fishes have been observed in nature, but in the aquarium experimentation on this question is not to be thought of. On the contrary, the authorities of the Naples station have to protect the basin for these fishes with bars and nets to prevent their escaping, because they would otherwise fly either through the window into the open air or to either side into the adjoining tanks. And, as a matter of fact, the station loses a rather large number of the fishes because they jump out and fall against the walls, or on the bridge over the aquarium, and perish there.

II.

The Dactylopterids are naturally carnivorous, but their food is determined by the size of the mouth and their environments. According to Schmidtlein, their small mouth permits them to swallow only small morsels; therefore they like to take crustaceans, such as shrimps (*Crangon* or *Crago*) and prawns (*Palaemon*), young crabs, and tiny fishes, which they find dead on the bottom.

III.

W. P. Calderwood and G. P. Bidder told Ernest Holt (1898) "that when a Dactylopterus was placed in a tank at Naples containing some small sharks the latter bit pieces out of its pectorals, a liberty resented by violent grunting." It is added that "gurnards and dories also grunt under circumstances of discomfort, the sounds being of the nature which appears from experiment to be perceptible by fishes. They may possibly subserve a function which is in part protective."

The Dactylopterids emit sounds under certain conditions, both in the water and out of it. While Calderwood was killing a couple of specimens "sounds exactly similar to those of the Gurnard were distinctly heard, and simultaneously with each sound a distinct contraction of the bladder could be felt from the exterior. These contractions were quite independent of any movements of the mouth or operculum." Schmidtlein never heard the sounds emitted voluntarily under water, nor observed the movement of the gill covers which produce them. Experiments relating to this subject were made by him and details promised for another place, but never published. The testimony of Calderwood and Bidder, however, supplies the deficiency in Schmidtlein's observations.

The sounds thus noticed are produced by the action of four muscles

upon the air-bladder already noticed. The muscles are two for each lobe, a large intrinsic and a small extrinsic muscle. The nervous impulses are communicated to them by the last pair of cerebral nerves. The intrinsic muscles, by contraction, produce vibratory quiverings (frémissements) which, reinforced by the bladder, become sonorous vibrations easily perceptible. These muscles, contracting while they vibrate, may change the shape of the bladder, stretching or relaxing such or such a part of the organ of this flexible sounding-board (instrument de renforcement), and by such changes modify the several qualities of sounds. The whole subject has been discussed at great length by Dufossé in his memoir on the sounds produced by European fishes, published in the Annales des Sciences Naturelles in 1874. In this article those who may be especially interested in the subject will find explanatory details. (See especially 5. serie, t. 20, article 3, pp. 47–51, 67, 68, 76, 80–84.)

But the air-bladder with its accessories is not the only sound-producing organ. The peculiar modifications of the suborbital bones and opercular apparatus are associated with a peculiar function—a stridulation which may be distinctly heard at a considerable distance. The pontinal or third suborbital bone is articulated so that it can be bent at a right angle with the enlarged second, and when the spiniform preoperculum is flexed outward the little pontinal is extended across and at a right angle between the reentering angle of the preopercular sinus and the second suborbital. When the preopercle is depressed and pushed forward and inward, its anterior articular surface grates upon the hinder angle of the lower jaw, and a distinct stridulatory sound is produced, reminding one of the strident notes of orthopterous insects, such as crickets or locusts, and grasshoppers. Attention was called to this fact and a full explanation given by W. Sörensen in 1884.

IV.

Oviposition probably occurs in the spring and the eggs are doubtless cast and fertilized near the surface of the water, and there the earliest days of the fish's life are spent. The earliest stages are unknown, but it is in the postlarval growth that the greatest interest is centered. When, or rather before, the young has acquired a length of a third of an inch, it has a helmet whose posterior processes reach as far back as the soft dorsal and the preopercular spines extend to the anal; at the same time the pectoral fins are short and entire, and the spinous dorsal little developed. This condition, so different from that manifest in maturity, continues, but with diminishing disproportion, till the length of nearly or quite 2 inches has been attained. Fishes possessing these characters were believed by the old ichthyologists to represent a peculiar genus, to which the

apt name *Cephalacanthus* (spined head) was given. But between the very little fish and the one about 2 inches long all gradations occur. With advancing age the spines become more and more reduced, the pectorals elongated, differentiation of each pectoral into two distinct parts supervenes, and the spinous dorsal is at length as large as the soft. The mature or true *Dactylopterus* stage is thus attained. This condition of maturity, however, may be hastened or delayed so that it may be attained when the fish is smaller than many which still have the attributes of immaturity, or it may be delayed until the fish has reached a length of 2 inches even. The transformation of the *Cephalacanthus* into the *Dactylopterus*, nevertheless, takes place rapidly at last.

V.

The Dactylopterids are not usually looked upon as game fishes, but Moseley, while on the *Challenger*, hooked one at Cape Verde of which he tells in his Notes by a Naturalist. "The trammel net was set nightly in the harbor by Mr. Cox, the boatswain, and yielded some fine fish. Among these were some flying gurnets, which evidently, from their being caught in the trammel, frequent the bottom a good deal like our wingless gurnets. One was caught with a line at the bottom. I hooked one, however, near the surface, when fishing with a rod and trout tackle for small mackerel and silver fish. This was quite a novel experience in fishing. The flying fish darted about like a trout and then took a good long fly in the air, and in an instant was down in the water again and out again into the air, and being beyond my skill in playing with such light tackle, soon shook itself loose and got free."

Moseley not only made an attempt on the fish as an angler, but also as a fowler. As the *Challenger*, on its way from Ascension Island, approached Boatswain Bird Island, and "as the vessel steamed along the shore of the main island, large flying gurnets (*Dactylopterus*)," it appears from the narrative (p. 298), "rose, scared by the vessel, and skimmed rapidly away in front of the bows. The attempt was made to shoot them on the wing, a novel experiment, but quite without success. The flight was rapid and the boat was in constant motion, pitching and rolling; no doubt in calm weather the thing might be done," thought the narrator.

The Dactylopterids are naturally quite sensitive to cold. At Naples it was practically impossible to keep a lot through the winter. According to Schmidtlein, their life is considerably shortened by the cold of the winter, and it has a very disturbing influence on their health, makes them sluggish and dull, and but rarely permits a specimen to live through the winter months till spring. The fish is, therefore, a periodical guest of the aquarium, the supply being renewed every season.

THE STATURE OF MAN AT VARIOUS EPOCHS.[a]

By A. Dastre.

An idea which has gained popular credence, and still hazily lingers in many cultivated minds, is that man of the present day is descended from a handsomer, stronger, and more superb ancestral race. In the course of time, it is said, the powerful sap that nourished the mighty bodies of our ancestors has, little by little, become corrupted or exhausted, until debilitated, feeble, and nervous generations have succeeded the productive, rich-blooded, and exuberant generations of old.

Without going to such an extreme, some students, more positive and more scientific, think nothing more than that the human body has undergone a sort of evolution of decline, manifesting itself in a progressive diminution in size. These ideas, which appear in various forms, becoming more and more veiled, are nothing else than remnants of an ancient superstition, the belief in giants.

What is a giant? Does it exist? Can a race of giants exist? Has such a race existed? These are questions that in all times have excited a lively interest. The imagination of the ancients was fed on stories in which the heroes were either giants or else mere pygmies. Even to-day tales about giants enliven our infancy. The reality of their existence excites such universal curiosity that it should not be cause for wonder that it has given rise to interminable and fruitless discussions among savants.

Of all these writings—of these innumerable fabulous stories of combats between giants and gods and the discussions about giants—nothing worthy of consideration remains. Recent works upon the subject are of more value. The problem now presents itself in a more practical aspect than it did to our predecessors. We have more records than they had; we are in a position to know whether man's size has varied in prehistoric and historic times, and whether there ever existed aggregations of colossal men meriting the appellation "race of giants." Since it is incontestable that individuals

[a] Translated from Revue des Deux Mondes, Paris, September 1, 1904.

of gigantic size do appear from time to time, a systematic study of the subject should be undertaken and would yield invaluable results. The research begins by investigating the significance and reason for the existence of these monstrous beings, and ends by learning why they can not reproduce and perpetuate colossal creatures like themselves.

Two sciences, anthropology and medicine, control the study of the subject, and the progress of our knowledge in the matter is due to both of them. The present article will deal with the subject chiefly from the anthropological standpoint, more especially in the light thrown upon it by contemporaneous anthropological research. The part which medical science played in explaining the causes of aberrations from the normal size is sufficiently definite and limited to warrant separate examination without inconvenience to the student. A word or two about it here will, therefore, be enough.

Anthropologists have applied the rule and compass to the study of primitive man, and they have measured in whole and in part the remains of our ancestors that lived in the geologic ages, the humble hewers of stone from the Quaternary age up to the dawn of the present era. Popular fancy exaggerated their size immoderately, for anthropologists, through the implements of an exact science, have found that instead of being giants they were men of only mediocre height. Anthropologists have also unearthed skeletons of men that lived since the beginning of the historic period, and measurements here, too, have proved that the average height of man shows no tendency to diminish. Scientists, then, by careful methods of measurement have furnished evidence in favor of the truth that Jean Riolan tried to establish as early as the beginning of the seventeenth century, and which he clearly expresses in the title of one of his works published in 1618, Discourse on the Height of Giants, in which it is shown that in all times, even the most ancient, the tallest men and the giants were no bigger than the giants of the present day.

To come back to the bearing of medical science upon the subject, it is medicine which has most recently thrown light upon the question of giants, and medicine maintains that to it belongs the study of giants in the present day, the rare few that now and then appear. Giants are men whose development instead of pursuing a normal course has undergone a morbid deviation, and whose nutrition has been perverted. They are dystrophic. Their great stature shows that one part has gained at the loss of another; it is a symptom of their inferiority in the struggle for existence. Their condition is not only a variation from the ordinary conditions of development—that is to say, they are "congenital monsters," the study of which belongs to the science of teratology—but it is a variation also from a state of

health physiologically and normally sound; that is to say, they are diseased and fall within the domain of the pathologist. "Here, then," as E. Brissaud says, "you have your giants despoiled of their ancient and fabled prestige; mythology yields the place to pathology." Such is the new doctrine in its most categoric or most expressive form.

The imagination of all ancient peoples was haunted by the chimerical vision of a sort of superman, like ordinary man, but bigger and stronger. These beings of perfect proportion, but of colossal stature, were giants. The conception has remained firmly fixed in popular belief, and it has been so general and so deep rooted that the question must perforce arise whether it did not have some foundation in reality. A priori, one is tempted to see in it the recollection, magnified by tradition, of a colossal race that actually existed. All mythologies, in fact, contain legends of giants. Greek mythology represents huge beings, children of the earth, carrying on formidable conflicts against the gods who inhabit heaven. The details of the struggle are recounted in a thousand different ways; now, it is an army of giants who stand in battle array under the leadership of Alcyoneus and Porphyrion and await the attack of the inhabitants of Olympus, aided by the hero Hercules. Another time it is Otus and Ephialtes, who pile mountain upon mountain to scale heaven and throw burning rocks against it. But the wars which break out over and over again always end in the triumph of the king of the gods; and the giants doomed to inevitable defeat are struck by Jupiter's thunderbolts, crushed under the wheels of his chariot, and finally hurled into Tartarus.

Historians and critics who insist that all myths have a significance symbolic and natural at the same time have no trouble to explain this one. They find in it a reflection and personification of the subterranean forces in revolt against the laws of nature—the Greeks said Divine laws—which require and maintain the solidity and fixity of the earth. These irregular, tumultuous forces, volcanic eruptions, earthquakes, violent cataclysms, these agents of destruction proceeding from the bowels of the earth and loosed against the order of the world; that is, against the gods, all these are giants. It is a remarkable fact that while the poets in symbolizing these natural forces gave frightful descriptions of them, endowing them with multiple members, with horrible heads, and enormous mouths spitting flames, the Greek artists, on the contrary, always susceptible to actual forms, represented them simply with human faces and figures. For example, in a painting on a very ancient vase the giant Antæus is represented as thrown into a prostrate attitude by Hercules and seeking to touch the earth with his hands in order to draw fresh vigor from it. His body, though that of a man admirably proportioned, is nearly double

that of Minerva, who strikes him with her lance, or that of Hercules, who draws a bow upon him. Moreover, the hugeness of the body is itself a rare and exceptional feature in the representations of the Greek artists, who quickly renounced this significant deformation, so that in ancient art giants would not have been distinguished from ordinary human beings if, after the archaic period, the custom had not arisen of terminating their lower limbs in the bodies of serpents. A beautiful cameo in the museum at Naples shows Jupiter crushing under the wheels of his chariot some serpent-footed giants whom he had already thrown to the ground with his thunderbolt.

Analagous legends have been transmitted to us by the historians of all the peoples of antiquity. Scholars have collected many references to giants in the Scriptures and in the writings of profane authors. Sometimes the huge beings form a whole people, or a tribe, or an ethnic group, though most frequently they appear in history as exceptional individuals. A list of references would be too long to be given here. It must suffice to mention a few sources of information, as Études biologiques sur les géans (Masson, 1904), by P. E. Launois and P. Roy. Buffon in his work on the natural history of man gives some information obtained from the Memoir of Lecat read in his day at the academy of Rouen. It is there recalled that the Greeks attributed to Orestes a height of 11½ feet, which Pliny consented to reduce to 7 cubits or 10½ feet. He also mentions the skeletons of Secondilla and of Pusio, preserved in the gardens of Sallust. These could not have measured less than 10 feet. In our time Prof. C. Taruffi, of Bologna, in his work (Milan, 1878) on gigantism—which he calls macrosomy—collected a vast number of records which show that the general belief has threaded history that modern man is the dwindled, degenerate offspring of ancestors of gigantic stature. From this point of view the isolated specimens of giants that appear at long intervals would be accidental repetitions of a vanished type, belated representatives of an extinct race.

This universal, deeply rooted prejudice rests upon evidence so manifold and so categoric that it might easily influence all but the scientifically equipped critic, and it is not until relatively recent times that the man of science himself has been in a position to discuss the evidence and cast doubt upon the belief. It may be of some value to recall that ideas upon the subject even in the nineteenth century were still sufficiently indeterminate for Silberman to feel justified in raising the question, in 1859, before the Academy of Sciences, as to whether the human body has varied in size within historic times. He answered the question in the negative. He affirmed that the stature of the Egyptians had not changed since the construction of the pyramids; but some uncertainty attaches to the calculations made by him for arriving at the height of the contemporaries of the king

Cheops in order to compare their size with that of the present generation.

The same uncertainty does not characterize the methods of modern anthropometry. Only limited faith is placed in the evidence of historians, geographers, or voyagers, and none but scientific measurements can be relied upon. The stature of vanished populations is obtained directly by measuring their skeletons or parts of their skeletons, the relations of which to the whole have been established by previous study and careful research. No one has gone further than L. Manouvrier in determining precisely the relation, long ignored, that exists between the various parts of a skeleton. For the use of anthropologists he codified after a fashion the rules outlined of old by Orfila and revised by Topinard and E. Rollet in France, by Humphry and J. Beddoe in England, and by Langer and Toldt in Germany. He made a sort of chart for ready reckoning, by the aid of which, from the dimensions of the femur or the tibia, we can deduce the height and the size of the body itself. The degree of approximation of the results is known, the extent of the extreme aberrations, the causes of the aberrations, and all the conditions, in short, for reducing the aberrations to a minimum. In these means of investigation contemporaneous anthropology has weapons with which to attack the prejudices that have long existed in regard to the gigantic stature of our far-removed ancestors and in regard to the pretended diminution in size which the human figure has been progressively undergoing.

Errors and exaggerations such as these have been collected, transmitted, and propagated by historians of all times. The first expression that they received is incontestably to be found in the Bible. The Hebrew scriptures allude in various passages to enormous men—as, for example, the population found by the spies of Moses in the Promised Land. The prophet Amos compares these occupants of Canaan to oaks for strength and to cedars for height. The simile forcibly recalls almost the very words of the Poèmes Barbares, in which the hordes of primitive men are described as they issue from dark woods and limitless deserts:

> More massive than the cedar, taller than the pine.

In the Book of Kings the giant Goliath is said to have been 11 feet 4 inches tall; and Deuteronomy narrates that the iron bed of Og, the King of Bashan, was 9 cubits, or about 15 feet, long. All the Jews, however, did not entertain blind faith in the accuracy of these figures, and many of them questioned how gigantic races, so powerfully built, could have completely disappeared. The prince of scribes, Esdras, who edited the canonical books at the end of the Babylonian exile and freed them of errors that had crept into them, pleads the progressive debasement of the race. Succeeding gener-

ations grow smaller and smaller; and so the colossal statures of the first men have dwindled to frailer forms. The opinion of Esdras appears among all peoples and in all histories of later times. The Greeks expressed the same idea of physical decadence, of a falling away from the grand stature of personages in the heroic age. Homer and Hesiod lament the decline, and, later, Herodotus, Pausanias, and Philostrates speak of it in a similar strain. Plutarch finally goes so far as to liken the men of his time to infants in comparison with the ancients. Among the Romans the same conception is found. Recall the lines of Virgil when the laborer with his plow turns up the bones and arms of his ancestors: "He gazes astounded on the gigantic bones that start from their broken sepulchers." Pliny in his natural history expresses even more extreme ideas in this regard. He mentions the discovery in a mountain of Crete of a human skeleton 6 cubits long, or more than 20 meters.

The moderns have had the same notions concerning the diminution of man's size. The historians of the Norse lands in many a passage celebrated the huge stature of the ancient inhabitants of Scandinavia.

Belief in the former colossal height of man and his continued decline in size through the ages seemed to be verified by the discovery of huge bones in ancient tombs. Lecat mentions tombs in which were found bones of giants 15, 20, 30, and 32 feet tall. But in his day scholars were no longer dupes of such evidence. It was known at the time—that is, in the second half of the eighteenth century—that the enormous bones were not those of human beings, but of large animals. In the opinion of Buffon they belonged to a horse or an elephant; for, he says, at one time warriors were buried with their war horses, and so, possibly, with their war elephants. But in less enlightened times, the bones were taken to be those of immense giants and were venerated as such. Sometimes they were exposed at cathedral doors. According to Langer, cited by Launois and Roy, one could see an exhibition of this nature under the porch of the chapel of the castle at Cracow as late as 1872. It was composed of a mastodon's bone, the skull of a rhinoceros, and one of the jawbones of a whale.

Of all these finds the most celebrated on account of the discussions to which it gave rise was made in 1613 near Romans, Dauphiné, by workmen engaged in digging sand. Near a building of brick they unearthed a skeleton 25 feet long. Now, it was pretended that a discovery of medallions bearing the image of Marius had been made in the neighborhood; and these two events sufficed as ground for the supposition that the bones were those of the giant Teutobochus, king of the Teutons, who had been conquered by Marius, near Aix, in 102 B. C, and had died soon after. Jean Riolan, physician and skillful

anatomist, said that it was an imposture to attribute the bones to Teutobochus. Other men, like Guillemeau, royal surgeon, and Nicolas Habicot defended the theory, and a controversy rich in incident lasted five years. The belief, which even in the time of Buffon seemed to lack the marks of verisimilitude, was not finally dissipated until De Blainville, in May, 1835, declared to the Academy of Sciences that the bones attributed to Teutobochus were those of a mastodon identical with mastodons previously found in Ohio.

For lack of populations of real giants, that is, men whose enormous stature separated them by a sort of hiatus from the tallest men one ordinarily sees, modern explorers have brought to our knowledge two races of men who are very tall without being inordinately so. They are called pseudo-giants. The two groups, representing the type of the tallest men on the globe, are the Patagonians of America and the Polynesians.

The Patagonians are especially interesting. Magellan was the first to see them, in 1519, on the strait called by his name, between Terra del Fuego and the American continent. Once during the five months of winter that he was forced to pass in this region, which he thought uninhabited, the Spaniards were visited by a native, come without doubt from some distance. He was gay, vigorous, confident, and he did not hesitate to go on board the vessel. In the written account of the voyage, the height of this savage is described as having been so great that the head of an average-sized man in the crew reached only to his waist. He was stout in proportion, his strength was considerable, and his appetite commensurate with his size. Having been well treated, he soon brought some of his companions of his own proportions. Magellan gave them the name of Patagonians.

If this description were to be taken absolutely literally, the Patagonians must have been about 8½ feet tall. Elsewhere, it is true, the author of the narrative ascribes to the natives only 7 feet 6 inches. It is interesting and instructive to note the variety of estimates made of their height by voyagers who have seen them. Magellan accords them 7½ feet; Commodore Byron 7 feet; the Dutchman Sebald de Noort 10 to 11 feet. Smaller size, however, is attributed to them by Commerson, traveling companion to M. de Bougainville and the Prince of Nassau. He says their height is not much greater than that of the average-sized Frenchman, usually from 5 feet 8 inches to 6 feet; none exceeded 6 feet 4 inches. This is far from being gigantic, as Commerson remarks, and he comes out very strongly against the fables and lies related concerning these pretended Titans. He is right. The Patagonians are men of great size, but they are by no means giants. Topinard, who forty years ago measured a fairly large number of their skeletons, assigns to them a height of 1.78m.

The general run of anthropologists admit the division of races or

peoples into four groups, according to their average height. The first group is that of the "tall-bodied," ranging from the English (1.703 meters), the shortest among them, to the Tehuelches of Patagonia (1.781 meters), the tallest, and including the Scotch (1.710 meters), the Scandinavians (1.713 meters), the Negroes of Guinea (1.724 meters), and the Polynesians (1.762 meters). The second group is of those "above the average" (1.65 meters to 1.70 meters), which, beginning with the French (1.650 meters) at the bottom of the scale, comprises the Russians (1.660 meters), the Germans (1.677 meters), the Belgians (1.684 meters), and the Irish (1.697 meters). The size of the third group, that is, of those below the average, ranges from 1.65 meters downward to 1.60 meters, and includes, among others, the Hindoos (1.642 meters), the Chinese (1.63 meters), the Italians of southern Italy, and the Peruvians. The last group is that of the "short-bodied," which includes, among others, the Malays and the Lapps.

The Patagonians, then, are only tall men, but they "hold the record," which fact, however, has been disputed, first, in favor of a population on the Upper Nile, the Dikas; next in favor of the Polynesians, then the Scandinavians, and last, the Scotch.

To recapitulate: There actually exists, then, no population or ethnic group of giants. Specimens of giants do appear, but only in isolated, individual, and accidental cases. Since physicians at the present time liken gigantism to a malady, we may say (from now on borrowing their language) that this disease is nowhere endemic, that it manifests itself a little everywhere, but in sporadic cases under the influence of conditions yet to be determined.

So much for the question of gigantism in present times. But the question is not one of the present; it is the past that perplexes, and it is the past with which we are concerned.

III.

As we have seen, it is in the past, in the long-distant past, in which tradition has placed the origin of a race of giants, who have subsequently undergone a process of progressive degradation. This thesis has been adopted by a fair number of writers more or less qualified to judge of the matter. Some of them, like Henrion in 1718, even ventured to draw up a table giving in positive figures the series of degradations undergone by the human stature in the course of time, from Adam, said to have been 123 feet (40 meters), Abraham, 27 feet (9 meters), and Hercules, 10 feet (about 3 meters), to Alexander the Great, 6½ feet (nearly 2 meters), and Cæsar, 5 feet (1.62 meters). These figures are so absolutely puerile and fantastic that they do not merit attention.

It is the task of anthropometry to try to estimate man's size in the

various epochs of history as well as in prehistoric times and geologic ages. For this it is necessary to arrive at some sure method of calculating the real size of the living being from his skeleton, or from fragments of his skeleton, found in the deposits of the Tertiary or Quaternary periods or in the sepulchers of historic times. The establishment of such a method of mensuration has for many years occupied L. Manouvrier, and it constitutes one of his best titles to a scientific reputation. The basic work that he published on the subject appeared in 1892; and recently, in 1902, he crowned his efforts, as it were, by issuing a study "upon anthropometric relations and the principal proportions of the body" (sur les rapports anthropométriques et sur les principales proportions du corps). The memoir is of great interest to natural history in general. Parts of it are well worthy the attention of artists, painters, and sculptors, whose classical canons, perhaps a bit factitious, ought to be submitted to the control of the science of man as he really is.

The results of the investigations made by L. Manouvrier can be expressed in a word. They have proved that man's stature has not undergone any important regular variation during the hundreds of thousands of years that have rolled by since his first appearance upon the globe. So far as one can judge from the isolated specimens brought to light by excavations, the stature of man has undergone no appreciable change. In this regard civilized man is the same as primitive man.

The study of animals has led to similar conclusions. In general, the body of animals of a certain species or of a certain variety is not modified; or if it is modified, the change has causes by no means displaying the character of a chronologic evolution. Geoffroy Saint-Hilaire, in order to show that man's stature has not necessarily changed since geologic times, based his argument upon precisely this fact, that the body of a domesticated animal species is identical with that of the wild species.

IV.

The furthest removed ancestor of man seems to be the famous *Pithecanthropus erectus*. In the course of the years 1891 and 1892, as may be remembered, a physician in the Dutch army, Eugène Dubois, discovered near Trinil, on the island of Java, some bones of puzzling appearance and with characteristics intermediate between those of a man and those of an anthropoid ape. There, in a deposit undoubtedly of the Tertiary epoch, was a complete skull, a femur, and two molars.

Simple as were these remains, they nevertheless sufficed for assigning to its proper place and rank in the animal hierarchy the being from which they came. It belongs between the anthropoid ape, the

gibbon, and man himself. The femur, whose form indicates adaptation to an erect posture, reveals man; the skull, whose capacity is too small for man but a little too large for an ape, reveals a superior anthropoid. The remains were in a state of fossilization corresponding to their antiquity and permitting them to be handled without danger of breaking them. They were exhibited throughout Europe and submitted to the examination of all competent anatomists—Krause, Waldeyer, Virchow, Luschan, Nehring, in Germany; Milne Edwards, E. Perrier, Filhol, in France; Cuningham and Turner, in England.

At Berlin the scholars brought into prominence reasons why the anthropopithecus could not be a man; at London they showed why it could not be an ape. So nothing was left the transformists but the conclusion that the creature, which was neither a man nor an ape, must be both at the same time, and that it constituted the transition stage from ape to man, the "missing link" of the chain that binds the human to the animal kind. E. Dubois assigned a height of 1.70 meters to the anthropopithecus; the estimate of M. Manouvrier is somewhat less. The length of the femur permits us to attribute a height of about 1.65 meters, the average height of the European, to this precursor, this original ancestor of man.

After measuring skeletons of the Tertiary epoch, as was done by M. Manouvrier, it was necessary to do the same for those of the Quaternary epoch. The task was undertaken by M. Rahon.[a] The most ancient specimen of that period is the skeleton of Neanderthal, found in 1857 in a limestone cave of Neanderthal, between Düsseldorf and Elberfeld. The first measurements, made by Professor Schaafhausen, showed that the relative proportions of the members were those of a European of average size or a little below the average. Schaafhausen determined the height to be 1.601 meters; Rahon's estimate, 1.613 meters, is almost the same.

It would be idle to give in detail similar measurements made of all the human bones of the Quaternary period that MM. Manouvrier and Rahon had before them either in the original or in casts. They computed the height of the man of Spy to be 1.610 meters, that of the man found in the clay of Lahr 1.720 meters. The latter, as is apparent, belonged to the group of "tall-bodied" men. The troglodyte of Chancelade, found in the more recent strata of Quaternary soil, was 1.612 meters, the crushed man of Laugerie 1.669 meters. The average for the four cases is 1.652 meters.

These figures would indicate but a moderate size in our distant ancestors, who were contemporaries of the cave bear and chased the

[a] It must be stated that the figures here given refer to the fleshly body, not to the skeleton. They give the length of the corpse as it would measure if stretched on the ground. Man erect and living measures 2 centimeters less.

mammoth and the rhinoceros of the chambered nostrils. They in no wise resemble the colossal beings created by popular fancy and described by the poets as "more massive than the cedar and taller than the pine." Nor were they "stronger than the oak." They lived more or less miserably. The men of the quaternary period had already begun to be industrious and they fashioned implements of roughly hewn stone. This was the beginning of the paleolithic or old stone age. It must have lasted a very long time, to judge from all the succeeding changes of climate and water courses.

V.

The following age is the neolithic or new stone age. Its duration was also very long, sufficiently long for Europe to be covered with its megalithic monuments and sepulchral structures. It was the time in which the cutting of flint, carried on toward a state of perfection, ended in the fashioning of various instruments for fishing, hunting, or fighting. These lost the rude character of the utensils in the preceding age, and the polishing of flint marked a turn in the affairs of prehistoric man.

The bony remains of the neolithic age underwent the same patient investigation and the same measurements as those of the paleolithic age; and Rahon and Manouvrier succeeded in determining the size of the people of this time, as of the preceding. Here the facts to work upon were much more numerous, for the number of skeletons that have been extracted is considerable. Conclusions were drawn from the examination of 429 men and 189 women. The average stature of the men is 1.645 meters, of the women 1.526 meters. But among these there were a number of tall and short persons, just as is the case at the present time. To cite several instances, the man of the Madeleine, the station next to Les Eyzies, in the department of Dordogne, measured 1.86 meters. The bones found at Les Eyzies belonged to still larger types. In this region Christy and Lartet exhumed from the cave of Cro-Magnon three well-preserved skeletons, which have given rise to observations of extreme interest to anthropology. They were the skeletons of an old man, an adult man, and a woman, and they have served as types for the establishment of a race become celebrated under the name Cro-Magnon. On a merely superficial examination of the bones, one can tell that the persons must have been robust and tall. Broca unqualifiedly declared their stature to be superior to the Frenchman's; but since it was impossible to reconstruct a skeleton in its entirety, he was not in a position to make direct measurements and give an indisputable figure.

Therefore it was with some hesitation that he assigned to them a probable height of 1.80 meters. Broca, it must be stated, for aid in his reconstruction could not fall back upon tables that would have

enabled him approximately to deduce the size of the entire body from nothing but the measurement of a single bone like the femur. Tables of this sort, it is true, existed in his time, provided by physicians who practiced forensic medicine, but they did not inspire him with confidence because the relations between the various parts of a skeleton had been established according to the principle of Paris or Lyon—that is, for the human structure as represented by the existing race of Frenchmen. But it is known that the relations between the various parts of the body are not the same in all the races of the present day; the principles for each are different. So much the more likely it is they would be different among prehistoric races. What is more, in a race like the French, there are two distinct types, each having the same measurement, but the one class is long-legged (macroscelic, in the term of the anthropologists), the other short-legged (microscelic). A priori it would seem as though all these difficulties would dash the hope of establishing a relation more or less fixed between the segment of a limb and the entire body. But these are the very difficulties that the methods of anthropometry were devised to overcome, and, as has been said, the method of Monsieur Manouvrier has succeeded.

Whatever the means employed (and it is useless to recall them here), Broca decided upon 1.80 meters as the height of the old man of Cro-Magnon. Some other investigators estimated it at 1.78 meters, and Topinard went so far as to say it was 1.90 meters, a figure altogether exceptional and unexampled up to this time in the case of prehistoric man. The estimates of Rahon and Manouvrier were lower. They fixed the height of the old man at 1.736 meters; that of the woman at 1.658 meters, and that of the adult man at 1.667 meters. Even these numbers betoken great height, superior, certainly, to the average height of the inhabitants of France. The race of Cro-Magnon, then, was a race of tall-bodied men.

The stature of the man of Mentone, whose skeleton was discovered by Rivière in ground of the neolithic period of the Quaternary age, was even larger. The caverns which exist in the red escarpments rising from the broken stone road between Mentone and Vintimille have furnished a fair number of bones, the last specimens being those of a child, a woman, and a man. Their fragility does not permit of their being handled and renders their measurement a delicate operation. From the tables of Monsieur Manouvrier the height of the man is calculated to be 1.752 meters. Monsieur Revière had reckoned it to be from 1.95 to 2 meters. It is clear that if one should consider the man of Mentone as the average type of the man of his time, the race to which he belonged would have been superior in stature to that which inhabits the same country to-day. They would have compared in size with the tallest actual races of Europe, the

Scandinavians or the Scotch. But there are many reasons for supposing that the man of Mentone ranked in the series of tall-bodied persons among the men of his own race.

In examining specimens of races inferior in stature to the French we find the man of Bolwillier measuring 1.60 meters; the skeleton in the sepulchral Caverne de l'Homme Mort in the department of Lozère, 1.62 meters; that in the cave of Géménos, 1.67 meters; in the cave of the valley of the Rousson, in the department of Gard, 1.63 meters. The man of the cave of Orrouy, in the department of Oise, represented a vigorous race and was 1.64 meters tall.

It would be irksome to prolong the enumeration. All the caves and caverns that have delivered up their human bones to the curiosity of anthropologists, the contents of all the sepulchral crypts, all prehistoric burial places, the dolmens of Belgium, of Quiberon, those in the departments of Lozère and Indre, the sepulchral vaults of a dolmenic character, like those of Crécy en-Vexin, the covered alleys like that of Mureaux, the peat districts of the department of Somme, and the dolmens of Algeria—the contents of all these have been examined and the bones found in them measured. The measurements made of more than 400 subjects (to be exact, 429) give us a more correct idea than we previously had of the stature of our ancestors in the neolithic period, and we are able to say with certainty that they were perceptibly shorter than the Frenchmen of to-day, their average height being 1.645 meters; that of the French, 1.650 meters. Therefore it is not true that we have undergone an evolutionary process of degeneration. It would be false to state that primitive man was our superior in stature.

Anthropological investigations bearing upon historic times scarcely offer anything more of interest to us, for one can tell in advance that measurements of the body would not furnish different results from those already set forth, since the stature of men of our race, which did not vary in the course of thousands of centuries during a period of extraordinary changes, would certainly not undergo perceptible variation in the course of a few hundred years during which conditions of existence have sustained but insignificant changes in comparison with those of preceding periods. Such, in fact, is the very conclusion to be drawn from the examinations made by Rahon and Manouvrier of the bones of human beings in various epochs of the historic period. In the first group they place the bones that may be called proto-historic, since they belong to a time the date of which has not been exactly fixed and of which no records remain. For example, in the museum of natural history (Paris) there is a collection of bones gotten together by M. de Morgan from the dolmens of the Caucasus near Koban and belonging to men who lived at an

epoch not exactly determined, which corresponds to the age of iron. These men are of those who constructed the megalithic monuments of Roknia and of the Caucasus, in which their remains are found. Their stature is hardly larger than that of the actual inhabitants of the country, the men reaching a mean height of 1.673 meters and the women 1.564 meters. According to Schortt, the average size of the present natives of Caucasus is 1.650 meters. Therefore we have an average height almost the same as that of the French.

In turning to France, an examination of the skeletons found in the Gallic or Gallo-Roman cemeteries of Vert-la-Gravelle, of Jonchery, and of Mont-Berny reveals a height of 1.66 meters in the men and 1.55 meters in the women. The Frankish populations buried in the sepulchers of the Department of Marne were 1.67 meters in height; those of the cemetery of Ramasse in the Department of Ain, considered to be Burgundians by M. de Mortillet, showed a height of 1.666 meters for the men and 1.538 for the women. The average stature of these peoples, who occupied France in the Gallo-Roman epoch, was a bit higher than that of the French nowadays, but not so much higher as one would suppose from the remarks of historians. With each investigation of each epoch the same conclusion is reached, and we repeat it as though it were the refrain of a couplet: Man's stature in the proto-historic period, as in the preceding period, was almost invariable.

The final researches of M. Rahon bear upon the Parisian population from the fourth to the eleventh centuries. The cemetery of Saint-Marcel was used in the fifth and sixth centuries, that of Saint-Germain-des-Prés more recently, in all liklihood in the tenth and eleventh centuries. The comparison and measurement of bones from these two cemeteries show that the average height of men and women is the same for both burial places, being 1.677 meters in the case of the men and 1.575 meters in the case of the women. The result gives rise to two observations. One is that in the course of six centuries the average height of Parisians has maintained a remarkable fixity. The other observation bears upon a comparison with the present stature of Parisians. A difference of nearly 1 centimeter (7 millimeters) in favor of the mediæval Parisians exists between the average height of present Parisians and those of the middle ages.

This is at once a great deal and very little. The greater size is explained by the fact that the bones which were put aside, guarded in collections, and finally submitted to measurement were the best preserved, the most solid, and those, in consequence, which, having most successfully resisted destruction, proved in themselves that they had belonged to the select. One such circumstance is sufficient to explain a slight difference of some millimeters.

It may be admitted as the result of pretty general experience—the

result, in fact, which arises from all that has so far been said in the present article—that when a race or people is sufficiently homogeneous, when it is not too mixed with other very dissimilar races, the average height is found to remain the same, provided enough measurements have been obtained. In the course of time it becomes invariable; it provides significant indications of great value. The amelioration of conditions of existence, which would appear to increase stature, does so only indirectly by eliminating a greater number of exceptional cases, which lower the average in a factitious manner. It excludes from comparison persons who, through disease or sickness contracted during the period of growth, have not developed harmoniously or attained their full height.

Nevertheless, it is important to state that the results announced some years ago by Manouvrier and Rahon have raised some objections. At first glance it is clear that all their measurements systematically lower the numbers generally assigned to man's height. In many cases the outcome of their exact methods contradicts not only general opinion, but the affirmations of historians and the results of approximate measurements. Objection was raised before the society of anthropology. A. Hovelacque, in particular, expressed his astonishment at the very low figure at which M. Rahon estimated the height of the Burgundians of Ramasse. All ancient authors agree in declaring the Burgundians, a Teutonic people, originally from North Germany, between the Oder and the Vistula, to have been extremely tall men. According to the measurements of M. Rahon they were only a little above the average (1.666 meters). If, as M. de Mortillet says is true, the men buried at Ramasse were Burgundians, and if the number of skeletons examined is enough to establish an average, one sees the consequences of the flagrant contradiction between anthropology on the one hand and historic evidences on the other.

M. Manouvrier replied to the objections made by A. Hovelacque. He declared that this contradiction did not affect him, since the determination of the size of the body from exact measurements of the long bones was an operation sufficiently precise to carry greater weight than the assertions of historians and geographers. Even the most exact historians, like Herodotus, Cæsar, and Strabo were capable of exaggerating the size of the people of whom they wrote. We have seen how the navigators and explorers of the eighteenth century, in speaking of the Patagonians, of individuals whom they themselves had seen, gave varying descriptions of them. Some set their height down as 6 feet, others at 7½ feet or more. Such facts as this may well put us on our guard against illusions of the eye, and still more against those of the imagination.

Even so, the figures given in regard to the height of the Burgun-

dians indicate that they were a tall-bodied race. Their stature is 16 millimeters, or nearly 2 centimeters more than that of the average Frenchman of to-day. And such a difference is not a negligible quantity. It makes an impression upon the eye, gratifying in its certainty, and it corresponds to the difference of judgment expressed when we say of a man that he is middle-sized, or of another that he is tall. For example, we call the Sardinians short and the Belgians tall; yet the average height of the Sardinians is only 2 centimeters less, and of the Belgians only 2 centimeters more, than that of the French.

The general conclusion of the studies sketched in brief in the present article can be nothing but a repetition of the conclusions reached at the end of each special study. The bones of primitive man, of prehistoric man, and, finally, of historic man, when submitted to examination, show that man's stature has experienced no appreciable changes in the course of time, has shown no traces of an evolutionary degeneration. We are not a stunted posterity, and we have the right to spurn the insult of the poet who says that "we are dwarfs beside our fathers."

OLD AGE.[a]

By Elie Metchnikoff,
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In compliance with the request of Doctor Toulouse, editor of the Revue Scientifique, I will try to give you an idea of the present state of our knowledge concerning old age, and I shall begin by speaking of the difficulty of the task which I have to perform. The problem of old age is one of the most complicated and difficult found in the biological field. As it is far from being solved it will be impossible for me to present to you a completed study with results sufficiently precise to be practically applied. On the other hand, the course of procedure which we pursue in studying this question has already been made public, and consequently contains nothing especially new.

The reason why, in spite of these disadvantages, I have accepted the proposition of M. Toulouse is because I wish to inform the public concerning the extent of our investigations upon old age and to make known what an immense field yet remains to be covered before we can arrive at a satisfactory solution of the problem.

In considering this question of old age we are beset on every side with difficulties. At what period of our life does this ultimate stadium begin; at what time ought a man to say that, having entered upon this stage of his existence he dare no longer conduct himself as an able-bodied individual? You will doubtless recall that it was but a few months ago that the students of the faculty of medicine in Paris loudly and noisily protested against the decision of the Senate that had suspended the law prescribing a limit of age for the professors. "We do not want old dotards," declared these young men. It is not rare to see old scientists of very great merit remain in their chairs up to an age when they are no longer capable of assimilating scientific progress, of judging correctly concerning new advances. Their auditors readily see that they are no longer abreast

[a] A lecture given in the Salle des Agriculteurs, rue d'Athènes, July 8, 1904. Translated, by permission, from the Revue Scientifique (Paris), 5th series, Vol. II, pp. 65–70 and 97–105.

with their coworkers; the old professors alone can not perceive this. As regards myself, if I had remained in my native country I would necessarily have been retired five years ago as having accomplished my thirty-five years of service.

You understand that, in view of this my task becomes still more delicate. Happily, in the present state of our civilization one risks only more or less disapproval. In the more ancient times or among modern uncivilized peoples the situation was and is much more serious.

Thus, throughout Melanesia it is the custom to bury alive old men who become incapable of useful labor. At Vate the old men have at least this consolation, that during the funeral ceremonies it is customary to attach to their arms a pig which may be eaten during the feast given in honor of the departure of the soul for the other world.

When the inhabitants of Tierra del Fuego are threatened with famine they kill and eat the old women before they do the dogs. One who asked why they did this was answered, "Dogs catch seals while old women do not."

Civilized peoples do not imitate the Fuegians or other savages. They do not kill and eat their superannuated members, yet the life of the aged often becomes very unhappy. Incapable of any useful work in the family or the community, old people are considered as a very heavy charge, and though we have no right to make way with them, we desire, nevertheless, their final departure, and are impatient at its long delay. The Italians say that "old women have seven lives;" the Burgomasks think that old women have seven souls, besides an eighth soul, quite small, and a half-soul besides, and the Lithuanians complain that an old woman is so tenacious of life that she can not even be ground in a mill.

These popular opinions have their echo in the frequent occurrence of criminal attempts on the lives of old men, even in the most civilized countries of Europe. In running through the chronicle of crimes one is astounded at the number of assassinations of old people, especially of old women. It is not difficult to find the motives of these criminal acts. A convict in Saghalien Island, condemned for the assassination of several old men, ingenuously remarked to the physician of the prison: "What's the use of making a fuss about them? They were already old, and would have died anyway in a few years."

In the celebrated novel of Dostojewsky, Crime and Punishment, the author takes his readers into a tavern where the young people are discussing all sorts of general problems. In the midst of the conversation a student declares that he "would kill and rob the cursed old woman without the slightest remorse." "In fact," he continues, "this is the way the matter stands: on one side we have a stupid, unfeeling old woman, of no account, wicked and sick, whom no one

would miss; on the contrary, who is an injury to everyone, who does not herself know why she keeps on living, and who perhaps will be good and dead to-morrow. While on the other hand there are fresh young lives wasting for nothing at all, without being helped by anyone; these can be numbered by thousands; everywhere it is the same."

Old men not only risk being assassinated; they often end their lives prematurely by committing suicide. Deprived of the means of existence, or attacked by serious maladies, they prefer death to their unhappy life. The frequency of suicides among old men is well established by statistics and supported by a quantity of precise data. This fact has long been known. New statistics tend to confirm it. Thus, in 1878, in Prussia there were 154 suicides per 100,000 individuals among men from 20 to 50 years of age, and almost double that, 295, among men between 50 and 80. Denmark, the classical country of suicide, confirms the rule. There were at Copenhagen, during the years from 1886 to 1895, for every 100,000 individuals, 394 suicides among men from 30 to 50 years of age, and 686 cases of self-murder among the old from 50 to 70 years of age. The young and strong adults furnished, therefore, 36½ per cent of suicides, while the number afforded by the aged amounted to 63½ per cent.

It is only in exceptional cases that these suicides can be attributed to the failure of the instinct of life. Most frequently life, although desired, becomes intolerable because of such circumstances as we have already mentioned. The desire to live, instead of diminishing tends, on the contrary, to increase with age. The old Fuegian women, aware that they are destined to be eaten, flee into the mountains whither they are pursued by the men and carried back home where they must submit to death.

It has for a long time been noticed that the longer one lives, the longer one desires to live. Charles Renouvier, a French philosopher, recently deceased, gave new proof of the truth of this rule. When 88 years old and feeling himself to be dying, he jotted down his impressions during his last days. This is what he wrote four days before his death:

"I have no illusions regarding my condition. I know that I am soon to die, in a week or perhaps two, and yet I have so many things to say about our doctrine. At my age one has no right to hope. One's days, or perhaps one's hours are numbered. I must be resigned. * * * I can not die without regret. I regret that I can in no way foresee what will become of my ideas. Besides I am going before I have said my last word. One always has to leave before terminating one's task. This is one of the saddest of the sadnesses of life. * * * This is not all. When one is old, very old, habituated to life, it is very difficult to die. I readily believe that young people accept the idea of death more easily than the old.

When one is beyond 80 years he becomes cowardly and does not wish to die, and when one knows beyond question that death is near a feeling of melancholy prevades the soul. * * * I have studied the question in all its aspects. I know that I am going to die, but I do not succeed in convincing myself that I am going to die. It is not the philosopher in me that protests. The philosopher in me does not believe in death, it is the old man, the old man who has not the courage to face the inevitable. However, one must be resigned."

It is seen then that in spite of old age, in spite of the wear of the spirit and the body, the instinct of life really increases with age. Old men desire to live, desire to continue to play their part and to go on with their work, as is proved by the old professors who do not want to abandon their chairs. Old men do not even renounce the tender passion. When 74 years old Goethe fell in love with Ulrica von Lewezow, a young girl of 17 years, and even proposed marriage. Failure in this project caused him great unhappiness, which he expressed in an elegy known as the Elegy of Marienbad. This is his plaint:

"An invincible desire distrains me; no resource is left me but eternal tears. Let them burst forth and flow on unrestrained. They can never extinguish the flame that consumes me. Already furious, it rages in my breast where life and death contend in fearful strife. * * * For me the universe is lost. I am lost to myself. The gods, whose favorite I lately was, have tried me; they lent me Pandora, so rich in treasures, richer still in dangerous seductions; they intoxicated me with the kisses of her mouth which gave so much delight; they snatch me from her arms and strike me with death."

This unhappy love suggested to the old poet some brilliant strophes, but the works of the last period of Goethe's life, such as the second part of Faust or the end of Wilhelm Meister, show a decided decline in his genius.

Old age is, then, the epoch of our existence which is full of the greatest contradictions. On the one hand there is a great desire to live, to be active, to love; on the other, the impossibility of realizing these desires. What are the characteristics of this period of human life which is so full of unhappiness?

II.

The aspect of old age is too well known for it to be necessary to describe it in detail. The skin of the face is dry, wrinkled, usually pale. The hair is white, the body more or less bent, the walk slow and difficult, the memory defective. Such are the most significant traits of the aged. It is often thought that baldness is characteristic of old age, but this opinion is erroneous, for the head begins to become bald at a comparatively early period. At an advanced age baldness follows its course, but whoever has not begun to lose his hair when young will not become bald during old age.

Stature decreases with age. According to numerous measurements men lose, between 50 and 85 years, more than 3 centimeters (3.166), women still more (4.3 centimeters). Sometimes this loss may reach 6 or even 7 centimeters.

Weight also diminishes during old age. According to Quételet, the maximum weight of men is attained at 40 years of age, of women at 50. From 60 years onward weight diminishes and at 80 years this loss amounts, on the average, to 6 kilograms.

The diminution in the height and weight of the body indicates a general atrophy of the organism in old age. Not only do the soft parts, such as the muscles and the viscera, become lighter, but even the skeleton loses weight in the old because of the diminution of mineral matters. This decalcification during old age, extending to all parts of the skeleton, causes a brittleness of the bones of the aged, which often leads to fatal results. One of the greatest representatives of medical science during the nineteenth century, Virchow, at the age of 82 years, in descending from a tramway, made a false step and broke the neck of his femur. In spite of all the attention that could be given him he died of the general exhaustion of forces after remaining several months in bed. Princess Mathilde fell in her chamber. This fall, which would have had no bad result in a young person, caused in this woman, 83 years old, a fracture of the neck of the femur. As in the case of Virchow a prolonged confinement to bed led to general malnutrition which terminated in death. This part of the skeleton, the neck of the femur, becomes particularly brittle in the old because of osseous atrophy.

The muscles are also much subject to atrophy during old age. They lose in volume, the muscular tissue becomes paler, the fat between the muscular fasciculi diminishes in quantity and sometimes almost completely disappears. Movements also become slower and muscular force diminishes. Measurements of the force of the hand and of the trunk, made by means of dynamometers, show a progressive diminution in the old. This enfeeblement is more pronounced in men than in women.

The volume and the weight of the viscera also diminishes, although in a different ratio for different organs. In order to explain the general atrophy of the body in old age an attempt has been made to ascertain the intimate structure of the organs and tissues of the aged. The visible manifestations of our organs represent the total of the functions of the microscopic elements that enter into their constitution. In order to understand the formation of the calcareous deposits upon which Paris is situated, and by aid of which its houses are constructed, it is necessary to consider the properties of the mollusks that have formed the shells which have accumulated and become cemented together to produce the stones. In the same way, in order to judge

of the senile alterations of our body, it is indispensable that we should study the changes that occur in the cells that compose it.

A great number of these elements are continually being lost. From the surface of our epidermis are detached minute scales composed of a quantity of flat desiccated cells that have become incapable of protecting our skin. The secretions of the mucous membranes daily carry away great numbers of the cells that make up those membranes. There is, therefore, a considerable wear of the microscopic elements of our body which must be reconstituted in order to maintain its equilibrium.

Under these conditions it was quite natural to ask whether the reparation of our cells is as well effected in the old as in those of adult life. This question arose all the more naturally because there are known examples of very low organisms that multiply by division, and which, after a considerable number of generations, finally fall into a state of exhaustion in which reproduction becomes gradually slower and more difficult, and may even cease altogether. This state of debility, which has been compared to senile atrophy, yields to certain influences, such as the conjugation of two exhausted individuals, or even to improved nourishment.

But since among inferior organisms, which resemble so much the cellular elements of our body, reproduction becomes exhausted at the end of a certain period, we are led to suppose that the same law may also apply to the senile atrophy of our own organism. Therefore, numerous scientists affirm that old age finally results because it is impossible for an organism to repair the cellular losses by the formation of a sufficient number of new elements—that is to say, because of the exhaustion of the reproductive faculty.

One of the scientists who have more especially concerned themselves with general questions, Weismann, expresses himself on this subject in a very categorical manner. According to him, the senile degeneration that ends in death does not depend on the wearing away of the cells of our organism but rather upon the fact that cellular proliferation, being limited, becomes insufficient to repair that loss. As old age appears in different species and different individuals at various ages, Weismann concludes that the number of generations that a cell is capable of producing differs in different cases. It is, however, impossible for him to explain why, in one example, cellular multiplication may stop at a certain figure, while in another it may go much further.

This theory appears so plausible that no attempt has been made to support it by precise facts. We even see, in the most recent attempt at a theory of old age, by Doctor Bühler, the thesis of the exhaustion of the reproductive power of the cells accepted and developed without sufficient discussion. It can not be denied that it is

during embryonic life that cells are produced with the greatest activity. Later on this proliferation becomes slower but it nevertheless continues to occur throughout the course of life. Bühler attributes the difficulty with which wounds heal in the aged, precisely to the insufficiency of cellular production. He also thinks that the reproduction of the cells of the epidermis which are to replace the desiccated parts of the skin diminishes notably during old age. According to this author it is theoretically easy to predict the moment when cullular multiplication in the epidermis must completely cease; as the desiccation and desquamation of the superficial parts continues without cessation it becomes evident that it must finally result in the total disappearance of the epidermis. The same rule is applicable, according to Bühler to the genital glands, the muscles, and all sorts of other organs.

These theoretical considerations do not, however, agree with well-known facts which speak but little in favor of a general diminution of cellular proliferation in old age. The hairs and the nails, which are excrescences of the epidermis, keep on growing throughout the entire life, thanks to the reproduction of the cells which constitute them. There is no arrest at all in the development of these parts even in the most advanced age. Far from that. We know that the hair that covers certain portions of the body increases in quantity and length in the old. In certain inferior races like the Mongols, the mustaches and the beard do not grow abundantly until advanced life, while young people have but small mustaches and very little or no beard. In women of the white race the same phenomenon occurs. The delicate and almost imperceptible down that covers the upper lip, the chin, and the cheeks of young women is transformed into veritable hair which forms the mustaches, beard, and whiskers of old women. Doctor Pohl, a specialist in everything that concerns the hair, measured the rapidity of growth of hair under different circumstances. He found that in an old man of 61 years the hairs of the temples grew 11 mm. in a month. But these hairs, in the same regions, in boys of from 11 to 15 years grew in the same time 11.8 mm., which represents almost the same figure.

There is therefore in the three subjects studied by Doctor Pohl no considerable diminution in the cellular growth in the old, in spite of the great difference in age. It is true that this observer showed that the hair of a young man between 21 and 24 grew at a rate of 15 mm. per month, while in the same individual at the age of 61 years the rate lowered to 11 mm.; but this slowing down of the growth of the hair was only apparent. In fact, the first figures related to hair from different regions of the hairy scalp, while the second related only to the hair of the temples. Now it is well established by Doctor Pohl himself that in the latter place the hair grows

more slowly than elsewhere. On the other hand, in boys from 11 to 15 years old, studied by this observer, the rapidity of development of the hair was always shown to be less than 15 mm. It was often even below the 11 mm. found in the man 61 years old.

In spite of the abundant growth of the hair in old age, these parts undergo a senile degeneration; that is to say, the loss of pigment. This blanching is doubtless an atrophic phenomenon which is not due to an arrest of cellular multiplication, but to the disappearance of colored granulations.

Let us now cast a glance at some other manifestations of old age. The debility of muscular movements is connected with modifications in the structure of the muscular fibers which also do not indicate an absence of reproductive power. The fascicles which form the muscles undergo a veritable atrophy, for they become much thinner than in their normal state. Besides there is deposited in their interior a quantity of fatty granulations, and, what specially merits attention, the nuclei of the muscular fibers show a very abundant multiplication, forming masses arranged in long series. Douaud, who has published a thesis upon the modifications of muscles in old age, remarks in this connection that the endogenous multiplication of muscular nuclei in old age is very active and that it takes place in exactly the same way as in the embryo. In this example of senile atrophy we are far then from finding a cessation of reproductive power in the cells.

As regards the brittleness of the bones in old people, this is also caused by cellular multiplication which produces large cells capable of destroying the osseous substance and making the bones spongy.

Detailed microscopic observation of senile organs has shown in a direct manner the existence of cellular multiplication. Thus Sackaroff observed it in the lymphatic ganglia of old persons, and among others in a man 102 years old. The few data just cited suffice to enable us to reject the theory that old age is caused by the exhaustion of the reproductive faculty of the cells. We must seek for another more comformable with the well-established facts of senile degeneresence. Without entering upon new details, let us try to comprehensively survey those we have already given. What common features connect the blanching of the hair with the atrophy of muscular fibers and the brittleness of the bones of the aged?

The loss of colored granulations in the hair is due to the setting free of a quantity of wandering cells which seize the pigment and transport it elsewhere, leaving the hair decolorized. In the atrophy of the muscles there is a multiplication of the nuclei and of the substance that surrounds them. As in the hair there are cells which devour the pigment, so in the muscles there are the multiplied elements we have just cited which devour the contractile substance. In senile

bone the osseous substance is destroyed by the giant cells mentioned above. In the cells of the senile organs just studied the general and essential phenomena consist, then, in the destruction of parts useful to the organism by wandering cells that present some traits in common with each other. They are voracious cells belonging to the category of elements designated under the generic name of macrophages. Certain macrophages remove the pigment of the hair, certain others destroy the osseous lamellæ, others still devour the contractile substance of muscles.

It is easy to prove that this activity or rather superactivity of the macrophages is observed in the most diverse organs of the aged. It is found in the brain, where the cells are in the act of devouring the most noble elements of our organism. In the kidneys and the liver of old persons there are found collections of macrophages that cause the secrètory cells of those organs to disappear, thus occasioning phenomena of atrophy of very great importance.

After having destroyed the noble elements of the aging organism, such as the nervous, renal, and hepatic cells, the macrophages become fixed in place and are transformed into connective tissue without ever being able to supply the place of the precious elements that have disappeared. It is in this way that there is set up in the aged that main factor of our premature decay, sclerosis of the organs. A study of the special phenomena of old age shows, then, that they arise from a cellular activity that brings about the destruction of the noble elements and the superiority of the macrophages. The latter, which in a normal state act as protectors of the organism against the invasion of microbes, at last themselves invade the most useful parts. There is produced in our body by the advance of age something analogous to what occurs in the old age of certain peoples when the army, intended to protect the state against exterior enemies, turns against the citizens of its own country.

In this invasion of the senile organs by the macrophages there sometimes occurs a veritable struggle between these voracious cells and our noble elements. Weakened by diverse causes these elements show signs of degeneration in the form of deposits of fat or of pigment. In these conditions of inferiority the cells of the brain, of the kidney, or of the liver more readily become a prey to the macrophages, whence results the loss of intelligence and the disorders of digestion and of the emunctories which are so common among old people.

But in other cases there can not be any serious question of a struggle between two categories of living elements. When the macrophages devour the pigment of the hair, or, indeed, destroy the osseous substance, there occurs rather an aggression of the macrophages upon inert parts that are incapable of defending themselves.

We have tried to show that the theory of the mechanism of old age

which attributes a preponderating part to the attack on the valuable elements made by the macrophages is not a mere plausible speculation, but rests on numerous and exact facts. It would be interesting to penetrate more deeply into the causes of this drama which is being played within our own organism and which occasions such serious evils. Unhappily science is not sufficiently informed to satisfy an investigating spirit otherwise than by the aid of hypotheses.

III.

It has often been said that old age is a kind of disease. In fact the great resemblance between these states is incontestable. Among the maladies to which an organism is subject there is a considerable group that manifest themselves in the form of atrophies. Sometimes it is an atrophy of muscles which occasions a considerable weakness in the voluntary movements and in which we find proliferation of the nuclei, as in the muscles of old people. Atrophic maladies of the kidneys and of the liver are numerous, and in these we find a disappearance of the glandular tissue and its replacement by connective tissues the same as we find in old age. Atrophy of the osseous substance produced by giant cells often occurs in the course of certain maladies. In all these examples the more profoundly we study the lesions the more we become convinced of their similarity to those which take place during old age.

Although the cause of many of the atrophic maladies is still unknown, there are nevertheless some whose origin is sufficiently established. Thus, among the atrophies of the muscles, we may cite that which is induced by the parasitism of trichinæ. The penetration of these minute worms into the muscular fascicles produces lesions that occasion multiplication of muscular nuclei and a destruction of the contractile substance.

The analogy with the atrophy of muscles is undeniable. The atrophic maladies of glandular apparatuses, such as the liver and the kidneys, are often occasioned by poisoning by alcohol, lead, and other chemical substances or they may be occasioned by some infectious microbic malady. Again, it is this latter cause which often leads to the destruction of the osseous substance. In certain infectious maladies like tuberculosis and leprosy the bacilli penetrate into the bones and succeed in forming there infectious foci. These bacilli are, however, incapable by themselves of dissolving and destroying the osseous substance, but the products that escape from them into the bones exercise an irritating action upon the giant cells which set to work to eat away the osseous lamellæ impregnated with lime. The tuberculous or leprous agent plays, therefore, only an intermediate part in the atrophy of the skeleton, which is immediately caused, as in

old age, by the work of the giant cells designated under the name of osteoclasts.

Since the mechanism of senile atrophy is entirely similar to that of atrophies of microbic or toxic origin, it may be asked whether in old age there may not be some intervention of microbes or their poisons. May not this abnormal excitation of the macrophages that leads them to destroy all sorts of noble cells of the organism and to even attack the pigment of the hair and the osseous substance be also due to the action of certain poisons elaborated within the body? The principal source of these poisons is clearly indicated: our digestive tube contains an enormous quantity of microbes, and many of them are capable of secreting substances that are more or less toxic. Our intestinal flora resembles the flora or forests in which there are found by the side of boleti and other edible mushrooms a great number of poisonous ones. It is true that our intestine is, up to a certain point, protected against the invasion of the microbes contained in it and even against their poisonous products. We may with impunity feed animals that are quite easily affected by certain infectious maladies upon the microbes that produce those maladies. Thus guinea pigs may swallow without harm great quantities of the bacilli that produce anthrax, but if there is the least lesion in the intestinal wall the mortal malady will declare itself. The presence of infectious microbes in the digestive tube may therefore have sad results.

The intestine is likewise protected against the absorption of certain poisons. We may, for example, cause guinea pigs to swallow, without effect, many cubic centimeters of tetanic poison, a hundredth part of a drop of which injected under the skin will inevitably bring on a mortal tetanus. The intestinal wall does not, therefore, absorb the tetanic poison. There are, however, other poisons that do not follow this rule and which are easily absorbed in the intestine. Cases of poisoning by poisonous mushroooms taken for edible ones are quite frequent. Neither is there any lack of microbic poisons that traverse the intestinal wall. We see arise from time to time veritable epidemics that are serious and even fatal as a consequence of the consumption of fish, meat, or conserves spoiled by microbes. In these cases there is usually an entrance into the intestines of the botulynic bacillus, which secretes a very violent poison readily absorbed by the organism in the same way as is the poison from noxious mushrooms. The symptoms of Asiatic cholera are also produced by a toxine elaborated in the digestive tube and absorbed by the intestinal wall.

But in the cases which we have just cited there occurs an acute poisoning, occasioned by the toxic products of microbes and of mushrooms introduced into the intestines. Now, there is no doubt but that there occur besides these examples others in which the poisoning is less violent and less rapid and in which the microbes of the intes-

tinal contents secrete their products for a long time, thus setting up a chronic poisoning. It is exactly among these products that we should seek for the cause of the weakening of our noble elements and the stimulation of the destructive activity of the macrophages. It is true that certain poisons once absorbed by the organism initiate the production of counter poisons Thus, Ehrlich, after having caused his mice to swallow quantities of vegetable toxines, ricine and abrine, proved that the blood of these animals became the best antidote against these poisons. The human organism after absorbing for years the microbic products elaborated in the intestines might indeed thus acquire an immunity with regard to them. This supposition is very probable, but it does not at all apply to a whole series of microbic poisons, such as the phenolic substances, the ammoniacal salts, and others, for their absorption occasions no production of counter poisons.

According to the hypothesis we are advancing, the principal phenomena of old age depend upon the indirect action of microbes that become collected in our digestive tube. And, since the wearing away of the substance of the bones in tuberculosis and leprosy is effected by osteoclasts excited by the poisons derived from the bacilli characteristic of those two maladies, so the same wearing away of the bones may come from a stimulation of the same osteoclasts by the poisons of intestinal microbes. If this is the case, our organism contains within itself the cause of its own destruction, in the same way that grapes carry upon their surface the germs of the ferments that set up alcoholic fermentation by destroying the sugar the fruits contain.

This hypothesis rests upon a great number of well-established facts, but it lacks direct proof, which can only be furnished by investigations carried on for long years. In this imperfect state it becomes necessary to bring together as many arguments as possible in order to justify our supposition.

If it is really intestinal microbes that are the cause of our senile atrophy, we must believe that the more the flora of the intestines is reduced the fewer manifestations of old age there will be.

If we compare an old mammal with an old bird we are at once struck with the great difference in their external appearance. An old horse or an old dog can easily be recognized by its ugliness, its lazy movements, its worn teeth, its lusterless hair turned white on certain portions of the body. A dog of 12 to 15 years shows very markedly all these signs of senile decrepitude. Birds keep their age much better and longer than mammals do. An aged duck, more than 20 years old, is alert in its movements and does not show externally any sign of its advanced age. Parrots and parroquets also remain for long years in a very youthful state. A little parroquet from 15 to 19 years old,

which I observed very closely for several years, manifested no signs whatever of old age. It was very lively and curious, interesting itself in all sorts of things about it, and its plumage was brilliant and richly colored. We have possessed for some years past a parroquet that, according to reliable information, must be from 70 to 75 years old. It is impossible to recognize its advanced age, so normal is its appearance and so easy are its movements.

The few examples just cited confirm the general rule that birds have a much geater longevity than the large majority of mammals. Now, birds are distinguished by having an intestinal flora very much poorer in microbes than that of mammals. Possessing no large intestine, birds lack that great reservoir for alimentary refuse which, in mammals, breeds an enormous quantity of all sorts of microbes. A very simple method of assuring ourselves of this consists in a microscopic examination directed toward ascertaining the comparative quantity of microbes contained in different parts of the digestive tube of a small mammal, a white mouse for example. We find quite a large number in the stomach; very few in the upper portions of the small intestine. The lower part of the small intestine contains many microbes, but it is in the cæcum and the large intestine that are found quantities truly enormous. The examination of the digestive organs of a small bird, a canary for example, having the same weight as the mouse above mentioned, gives quite a different result. In canaries microbes are found, but in very small numbers. The stomach and the small intestine contain throughout their course only a few isolated specimens. The inferior portion of the intestinal tract contains a few more microbes, but their number is very far from being equal to that found in the mouse. The cæcum, that large reservoir for intestinal microbes in the mouse, is represented in the canary merely by two rudimentary culs de sac destitute of microbes. It is not astonishing that, under these conditions, the toxic effects derived from intestinal sources should be much less in the canary (and in birds in general) than in the mouse and most other animals. So we see that while the mouse is already old after a few years, and lives hardly five years at most, the canary is vigorous for a much longer period and may attain the age of 15 or even 20 years.

When we see that cold-blooded vertebrates, such as turtles and crocodiles, attain a very advanced age without showing any extensive signs of senility, we are tempted to ascribe this fact to the rather inactive life of those animals. As they do not need to maintain a high bodily temperature, they take but little food and are not forced to expend much energy in procuring it. Birds have none of these advantages. They lead a very active and agitated life; in order to preserve their normal condition they must maintain a higher bodily

temperature than is necessary for mammals, yet they attain a greater and more active old age than do mammals, even including man.

Notwithstanding the great difference between the life of birds on the one hand and that of turtles and crocodiles on the other, these animals have this point in common, that in them the large intestine is very slightly developed, if not absent, and their intestinal flora is extremely scanty.

In spite of the imperfect state of our knowledge at the present time, the mass of facts we have cited may well justify us in maintaining the hypothesis that the intestinal microbes play the part of one of the preponderant causes of that chronic malady, our old age.

Since science has already found very efficacious means both for protecting the organism against infectious maladies and for curing such maladies when they are not too far advanced, why should not one seek for something to render old age less painful, it also being a state which should be considered as having a microbic origin?

If, as seems more and more probable, the source of our early decay is found in our intestinal flora, we ought to seek some means either for eliminating it more or less completely or for modifying it profoundly. The idea of suppressing the large intestine, that useless part of our digestive tube that we have inherited from our animal progenitors and that serves as the principal reservoir for noxious microbes, can not be considered seriously. It is evident that we can not count upon the extirpation or even upon the surgical exclusion of the large intestine. In the cases in which this operation becomes unavoidable we find that the organism tends to form a second large intestine. We have under observation at the present time a young woman in whom the suppression of the greater part of this organ, made nearly a year ago, has by no means suppressed the disadvantages due to intestinal microbes. It even seems that there is produced at the expense of the remaining portion of the large intestine a pocket which collects the alimentary waste and nourishes a multitude of microbes.

In the present state of our knowledge we are inclined rather to consider the question of modifying our intestinal flora. There is now present in it many injurious microbes. It is only necessary to have some lesion in the intestinal wall that allows these to escape into the peritoneum to set up an infectious disease of the gravest character.

The microbes capable of inducing putrefaction are among the most dangerous. Now, these microbes have bitter enemies in other microbes, especially in those that set up the fermentation of sugars and produce lactic acid. Are there no means of acclimatizing such microbes within our digestive tube in order to combat with their aid intestinal putrefaction?

Bacteriological researches have shown that many microbes, even

when taken in very large quantities, perish in the intestines of man and of animals. Thus, for example, the vibrio of cholera, that dread agent of Asiatic cholera, has many times been swallowed with impunity by various persons. Its destruction was so complete that it was impossible to find it again in the alimentary waste. Schütz introduced directly into the small intestine of dogs a quantity of vibrios which he saw soon after had disappeared. The same phenomena were observed in chickens, the microbes being destroyed in their digestive tubes.

In every attempt at a modification of the intestinal flora it is, then, necessary to find out whether a given microbe is really capable of living in the intestines. For certain lactic microbes this fact has been established by experiment. In curdled milk prepared by a ferment of Bulgarian origin, placed at our disposal by Professor Massol, at Geneva, there is found a large bacillus remarkable for its ability to produce a great amount of lactic acid. This bacillus, when swallowed by man, does not suffer the fate of the vibrios which we have mentioned. It is not destroyed in the intestines, but passes through alive. Its presence has been demonstrated by Doctor Cohendy even many days after its introduction by the mouth. Here, then, is a microbe not normally present in our intestinal flora which may be implanted there artificially, either with curdled milk or under the form of a pure culture; endowed with great power of producing fermentation, it will be capable of effectively combatting intestinal putrefactions.

It is interesting to note that this microbe is found in the sour milk consumed in large quantities by the Bulgarians in a region famous for the longevity of its inhabitants.

We have, then, reason to suppose that the introduction of this Bulgarian clotted milk into our diet may counteract, or at least diminish, the injurious effect of the intestinal flora. This would be the first example of artificial modification of that flora.

To sow useful microbes within our digestive tube is not sufficient. It is also necessary to prevent the introduction of injurious ones. With this end in view we should avoid, as much as possible, uncooked foods that serve as vehicles for all sorts of microbes. In spite of the washing of vegetables and fruits, such as salads, radishes, strawberries, cherries, and others, they are yet contaminated with dust, soil, manure, and fecal matters. Now, these often contain injurious microbes and eggs of animal parasites. Doctor Bienstock found in the earth of his strawberry beds tetanic spores, which he found would be destroyed in his own digestive tube when a little of that earth was swallowed. But we must not count too much on the antimicrobic power of our intestines, and it is much more prudent not to use these vegetables and fruits until they are cooked—that is to

say, until after the destruction of all or a large part of the microbes that they contain. This measure, together with the use of water that has been boiled, will prevent, once for all, the penetration into our body of wild microbes whose injurious effects can not be denied.

Thanks to the means we have just outlined, as well as to others which we may add thereto later on, we may in the future transform our intestinal flora, now so varied and uncultivated, into a flora of much fewer species, exempt from injurious microbes but containing useful ones—in a word, into a cultivated flora.

But independently of this prospect, it is possible to avoid the disadvantages of our present intestinal flora by specific serums, prepared with a view to neutralizing the injurious action of certain microbic poisons and of destroying the microbes themselves.

As, according to our hypothesis, these microbes act upon our organism by weakening our noble elements and stimulating their adversaries, the macrophages, it will be rational to seek the means for reinforcing the former. The weakening of the latter can not be considered for the moment, as the macrophages are of great use to us in the struggle against several infectious diseases, and notably against the most terrible of all, tuberculosis.

The idea of reinforcing our noble elements is based upon the study of certain poisons called cytotoxines. Not being able to enter into the details of this question we will content ourselves with remarking that, while strong doses of these poisons destroy our cells, minute doses, on the contrary, reinforce them. We should, then, attempt to assist our noble elements in their struggle against the macrophages by the aid of cytotoxines. This problem is complex and delicate, and requires numerous preliminary researches of long duration. These were begun a year ago. At this time the question is not sufficiently mature for any kind of discussion.

The theory of old age and the hypotheses which are connected with it may be summarized in a few words: the senile degeneration of our organism is entirely similar to the lesions induced by certain maladies of a microbic origin. Old age, then, is an infectious chronic disease which is manifested by a degeneration, or an enfeebling of the noble elements, and by the excessive activity of the macrophages. These modifications cause a disturbance of the equilibrium of the cells composing our body and set up a struggle within our organism which ends in a precocious aging and in premature death, contrary to nature.

It is very probable that during the time we are growing old the intestinal microbes that have set up within our body permanent factories for different poisons play a very important part. It is, then, entirely possible to struggle against premature senility by modifying

our intestinal flora and by reenforcing our noble elements, so sensitive to microbic poisons.

But, you may say, all this is theoretical. It may be scientific, but it has not been proven. You may ask me to speak to you of our present established knowledge concerning old age, of what modern medicine proposes to do in the way of remedying this unenviable condition. This question has for a long time been under consideration, and I will now give you the last utterance of empiric wisdom. A much-esteemed physician of London, Doctor Weber, who is himself very old, has quite recently summarized the means that he used to make his own age supportable and to ameliorate that of his numerous clients.

These are the rules that he drew up for this purpose: "All the organs must be preserved in a state of vigor. Morbid tendencies, whether hereditary or acquired during life, must be recognized and combated. Moderation must be used in the consumption of food and drink as well as in the pursuit of other corporeal pleasures. The air within and about the dwelling must be pure. Corporeal exercise must be taken daily in all conditions of weather. In many cases it is also necessary to take respiratory exercises as well as to walk and climb. One must retire early and rise early. Sleep should be limited to six or seven hours. Every day a bath should be taken or the body be well rubbed. The water employed for this may be cold or warm according to individual temperament. Sometimes warm and cold water may be alternately employed. Regular work and intellectual occupation are indispensable. The mental attitude should be that of enjoyment of living, tranquillity of mind, and a hopeful conception of life. On the other hand, the passions and nervous disturbances of sorrow should be combatted. Finally, one should have a firm determination that will compel the preservation of health, the avoidance of alcoholic liquors and other stimulants as well as narcotics and analgesic substances."

These counsels are certainly very useful to follow, but very frequently they are insufficient for the attainment of a normal old age. Many very sober persons, not addicted to alcoholism nor any other excess, contract chronic maladies of the kidneys, of the blood vessels, of the digestive organs, and of the nervous system which result in premature and most painful old age.

Empirical rules, even when dictated by the widest experience, can not, then, suffice to solve the problem, and we must seek the aid of science in order to obtain an effective result. The scientific study of old age is therefore indispensable. In order to make this study possible, we must, first of all, have material upon which to work; that is to say, old people, and, indeed, many old people. The opinion that

old people are merely a burden upon society, which ought to support them simply because of our moral laws, is certainly erroneous.

Not only do the young, but many older persons share the opinion that old people incapable of work are no longer good for anything. Some ten years ago a celebrated German physiologist, who had reached a great age, told me how he felt because of his uselessness to society, and added: "What can one do? I can not decide to kill myself." Well, now that science has taken up seriously the study of the problem of old age, old people have become very useful subjects, especially so for the young, who may be able to profit by the results of these studies. If we should make way with the aged, as certain savage tribes still do, old age could never be modified nor ameliorated. If we should make way with the sick, as was formerly done, and as is still done among certain tribes, we should never discover any means for curing diseases. If we had killed diphtheritics under the pretext that the greater part of them were going to die and that they were a source of danger to their healthy neighbors, we should never have discovered the serum which now cures them.

Old people, even in their condition of decrepitude, may be very useful, on condition that scientists can be found who will undertake the task of carefully studying them. There is also a certain consolation in the thought that when we ourselves have become incapable of studying old age we may serve as subjects of study to other observers. In any case, it is to be hoped that in the future, which is, without doubt, somewhat distant as yet, old age may cease to be one of the greatest misfortunes of humanity, and that this chronic disease may yield to the ever-increasing progress of exact science.

CONTRIBUTIONS OF AMERICAN ARCHEOLOGY TO HUMAN HISTORY.[a]

By W. H. Holmes.

The importance of archeology to the student of history is now fully recognized. The science is establishing its claims to consideration more fully year by year, especially since it has become allied with geology, which furnishes the necessary time scale, and with paleontology, which supplies the scale of life. The branch of inquiry which only a few years ago dealt with isolated fragments of knowledge, with disjointed portions of the framework of human history, now essays to aid in building up the entire skeleton of that history, and, with the aid of the allied sciences of ethnology and psychology, in clothing it with the integuments of a living reality.

America is taking a noteworthy part in this rehabilitation of the race and, fortunately, is most helpful just where the Old World is weakest. In America the past of man, for the most part at least, connects directly with the present and with the living. Each step backward along the course of culture development proceeds from a well-established and fully understood base, and there is thus no baffling gap between history and prehistory, as in the Old World.

In America all the steps of culture from the highest to the lowest within the native range are to be observed among the living peoples, and we are thus able to avoid many of the snares of speculation with respect to what men have thought and men have done under the greatly diversified conditions of primitive existence.

In America the conditions are simple. The antiquities of a region represent in a large measure the early history of the known peoples of that region. There have not been the successive occupations, the racial interminglings, the obscuring and obliteration of phenomena that so seriously embarrass the student of the ancient nations of the

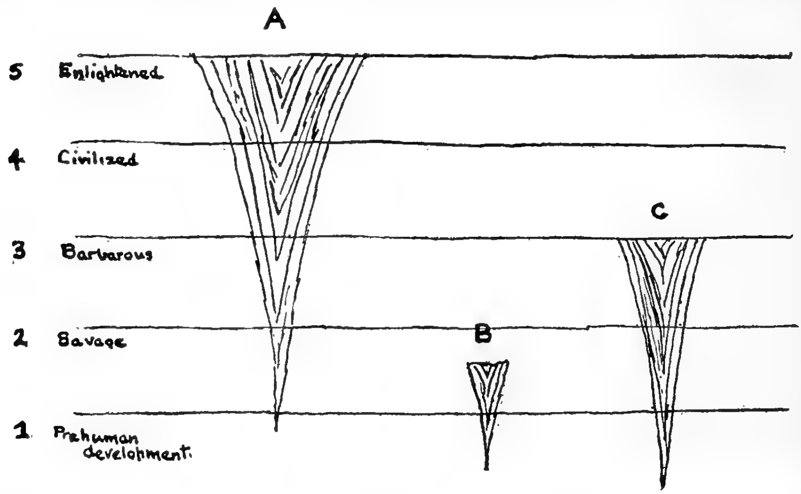
[a] Paper read before the Congress of Americanists, Stuttgart, Germany, August 21, 1904.

Old World. The stone age and the red race stand practically alone within the field of study.

In America the high-water mark of culture barely reached the lower limit of civilization. In the Old World the fuller representation of man's career is above that limit, so that America can be expected to assist, especially in building up the substructure of human history. It can be expected to furnish a fuller reading of the early chapters of culture progress than any other part of the world.

The position of aboriginal America in the field of culture history and the area of that history which American archeology, as well as American ethnology, can be expected to illumine is clearly indicated in the accompanying diagram.

In this diagram the whole field of human history is represented by the five spaces which, beginning below, are: (1) The stage of prehuman development, through and out of which the race arose; (2)



the average stage, in which humanity took definite shape; (3) the barbarous stage, in which powerful nations were founded and systems of record were developed; (4) the civilized stage, in which higher culture was achieved, and (5) the enlightened stage, reached as yet only by a limited number of nations. The idea of time is not involved in this diagram. The stages of progress thus become a scale on which the cultural achievements of any race or people in its struggle upward may be laid down. It enables us to show just what relative place is taken by each race or people and just how much and at what points each can contribute to the history of man; for human history as written is composite, made up of the separate histories of many peoples of all grades of development set together as a mosaic.

The fan-shaped figure A in the diagram may be taken to express the history of the race; that is, the whole of human progress from

the slender beginnings of the savage stage up to its greatest expansion at the present day. The same figure may stand with equal propriety for the career of a single people or nation that has reached the highest limit of culture. In the diagram, the beginnings of cultural development are represented at the base of the figure by a few slender threads of activity. In savagery these threads multiply slowly into a considerable number and, with ever accelerated rapidity, divide and subdivide in barbarism and civilization, expanding with marvelous rapidity in the horizon of enlightenment. While this expanding figure may be regarded as expressing the growth of human culture, it may also symbolize the development of the race in population and in physical perfection.

The figure indicated by B may stand for the career of peoples of the lowest existing order of culture, such as the Fuegians or Andamanese—peoples which can contribute to general history only within a very limited range, since their career traverses only the lower half of the field of savagery. It is to be noted, however, that these lowly peoples can contribute much more fully to the history of this particular stage of progress than can any of the nations that have passed this stage and have risen to higher levels.

The field covered by the American race is outlined in C. Uncertain and indefinite in the beginning stages, the traces being hardly legible on account of the absence of written records and the insufficiency of archeological research, it develops upward, stopping just short of the level of civilization. Many strands of culture had appeared and had grown strong, but writing had not been fully achieved and other arts peculiar to civilization had not made their appearance. It is within this field that Americanists pursue their studies and make their contributions to the history of the race and of developing civilization. Above this stage they find nothing and below it only meager and uncertain traces of the beginning stages of human culture. The archeologist finds within this limited American field, however, extensive phenomena relating to the various branches of barbarian activity, especially to such as leave their traces in material form. Prominent among these branches are agriculture, hunting, fishing, quarrying, and mining. The shaping of implements and utensils, the building arts, metallurgy, sculpture, ceramics, the textile arts, the graphic arts and writing, war, games, culinary arts, religious arts, personal adornment, the decorative arts, etc. These groups of phenomena, as exhibited in America, have been the subject of earnest study by a large number of scholars and already a great body of data relating to them has been collected and an extensive literature is in existence. A few of the more instructive of these groups may be briefly reviewed.

Quarrying and mining.—Much of the history of the activities concerned in the acquisition of the raw materials of subsistence and the

arts is best studied among existing peoples. This is especiallly true of hunting and fishing, the gathering of wild fruits and grains, and agriculture. But archeology alone can be depended upon to tell the story of the industries concerned with developing the mineral resources. These activities escaped the observation of the conquerors and colonists and were discontinued so abruptly that very meager records of their operation have been preserved. The story of the struggles of primitive man in exploiting the valleys and mountains and in extracting the staple materials of the stone-age culture from their rocky beds forms one of the most interesting and important chapters in the history of incipient civilization. With implements of stone, bone, and wood the aborigines attacked the massive strata, breaking up solid bodies of flint, quartz, obsidian, jasper, etc., for the manufacture of implements and carving out huge monoliths from the living rock for building and sculpture. A study of the American mines and quarries gives us a vivid conception of the strength and persistence of the forces that underlie human development, and of the difficulties encountered by the race in carrying culture upward through the stone age to the higher level of the age of metal. The shaping of the stone into implements and utensils supplemented the work of the quarryman, and the story of the development is clearly told in many lands. But America's contribution to the history of this most important branch of activity is exceptionally full and satisfactory.

Architecture.—Aboriginal architecture in America teaches the lessons of the initial development of this branch of culture with exceptional clearness, beginning at the lowest stage and carrying it up to about the stage of the keystone arch. The present period affords a wide range of phenomena representing the elementary forms of building, and post-Columbian chronicles give us somewhat meager glimpses of the higher development that came under the observation of the Spanish conquerors, whilst archeologic remains supplement the lessons of the historic period. We find constructions of great variety and of remarkable preservation in the Mississippi valley, in the Pueblo country, on the Mexican plateau, in Yucatan, Guatemala, and Honduras, and in South America. By the aid of these we see how the midden and the earth mound develop into the pyramid with its multiple stairways of cut stone; how the walls change from irregularly placed stone, and clay-covered wicker to massive structures of accurately hewn stone; how the chamber spaces, ceiled at first with weak timbers subject to quick decay, are spanned later by the offset arch of stone. We see supported on this native arch the concrete roof, so massive as to defy the earthquake and support the forest growth of successive centuries; we see the multiplication of stories, tier on tier; we see the spanned space, limited at first to a few feet, increase indefi-

nitely to the many-vaulted roof supported by a wilderness of limestone columns; we see walls decorated within and without with symbolic sculptures, single buildings presenting thousands of square yards of embellished surface, and marvel at lofty false fronts and roof crests that were added to afford space for the exercise of the native genius for decoration.

These chapters in the evolution of the building arts are not taught with equal clearness and fullness in any other part of the world. Besides the direct lessons which bear upon the history of the art of architecture, many side lights are thrown upon other branches of primitive culture—mural decoration, sculpture, and furnishing, as well as the organization of society, religious beliefs, and systems or writing.

Sculpture.—Sculpture reached its highest development in Greece, but the stages through which the art passed are but meagerly recorded in the extant art works of Hellas. The earlier steps are represented by isolated bits in many places, but the primitive phases of the art are by no means so fully exhibited as in America. We have there a vast body of material covering every stage from the very beginning of stone-shaping up to full relief and realistic portrayal of the human subject. No people known to us has within the culture range of the Americans shown such versatility and power with the hammer and chisel; none has embodied in stone a mythology so rich in imagery, including as it does forms of men, beasts, monsters, and cosmic phenomena in greatest variety. The archeologist has here spread out before him, with the work of the living peoples to guide him, as in an open book the whole story of the evolution of sculptural phenomena within the horizon of barbarism.

Metallurgy.—The working of metals is among the most important activities of civilized man, and has been a chief agency in the development of culture, as is especially manifest in gigantic forward steps of recent years. Although the general course of metallurgic development and the mutual relation of its successive stages of progress are well made out, much remains to be learned, and in this direction America is able to make the most valuable contributions. We learn from history something of the metal work of the American aborigines. Tin, lead, and iron were little known, and the smelting of ores was in its infancy, but gold, copper, and silver were extensively employed when the Spaniards arrived, and these metals were forged, fused, cast, alloyed, plated, and otherwise handled with a skill that astonished the conquerors. Archeology verifies the statements of historians and adds much to our knowledge of the manipulation of metals and of the forms produced in the primitive stages of culture, not only in regard to the Western Continent, but for the general his-

tory of the subject at periods where the records in the Old World are most defective.

Ceramics.—Of art in clay we may say much the same as of sculpture. No people known to us has furnished such a vast body of material for the study of this art from its beginnings up to the level of glaze and the wheel as have the pre-Columbian Americans. The clay took on a multitude of forms in which were embodied a wide range of mythologic and esthetic concepts.

The graphic arts.—To the history of writing aboriginal America makes many contributions, and these, like the others referred to, fall within that part of the history of progress wherein Old World evidence is least satisfactory. In the Old World we trace back the history of writing step by step to a point near the beginning of the glyphic system. In the New World we pass back from the lower margin of the glyphic to the very beginning of the graphic, thus all but completing the history of the evolution of the recording arts.

With a knowledge of the present and prehistoric phases of picture writing, it is easy to utilize and interpret the vast body of material in this branch furnished by archeology; but, rich as is this material, insufficient light is thrown upon the transition from picture writing to phonic writing, the particular stage of development in which archeologists find one of the most fascinating fields of research. The great body of evidence brought before the conquering Europeans was not appreciated by them, but rudely destroyed, and the remains, graphic and sculptural, are now being gathered together and studied in the most painstaking manner by our scholars, who hope almost against hope to find a key to the problems of transition. Within the cluster of graphic phenomena which gave birth to writing, we have evidence bearing upon other important branches. We here get glimpses of the history of the calendar; we find traces of the pictorial art, which had not yet reached the stage of light and shade, perspective, and portraiture, and discover many germs of embellishment, both mythologic and esthetic.

Although many of the obscure problems arising in this American field have been successfully worked out, many others are still awaiting the attention of Americanists and will no doubt yield, little by little, to their persistent efforts.

The more important unsolved problems of aboriginal America are those of race origins, of culture origins, and of chronology. These problems do not relate so much to particular nations as to the history of the race as a whole; not so much to peculiar or local cultures as to the origin and evolution of the native activities; not so much to tribal or national chronology as to correlations of race and culture history with the geological time scale.

With respect to race and racial characters American archeology

has as yet little to add to what may be learned from studies of the living peoples. So far as observed, the variations in type of fossil forms do not extend decidedly beyond the range of variation observed among the living. It has been sought to establish a paleo-American type in South America, but we are not certain that a sufficient comparative study of the osseous remains of the present peoples of the world has been made to warrant a satisfactory determination. Conservatism is especially desirable in any attempt to establish new racial types or special orders of culture.

Regarding race origin it may be said that there is still room for speculation. Opinion seems, however, to be settling down to the view that the American race, as it stands to-day, is not autochthonous, but is an offshoot of Asiatic peoples, originally more or less diverse in character and arriving in America, mainly at least, by the Bering Strait route, not abruptly, but in the normal course of race distribution from a natal habitat, the migration continuing for untold centuries. Americanists have here a difficult, a perplexing, but a most fascinating, field of research.

To-day, one of the most absorbing questions encountered by the student of American archeology is that of the origin of the aboriginal cultures. Some regard these cultures as autochthonous; others have looked for their source in many different parts of the world. Although no final conclusion can yet be announced, we may assume that, along with the incoming peoples, all or most of whom must have been extremely primitive dwellers of the far north, there came the simplest forms of the arts of hunting, fishing, shelter-building, and the preparation of food; that from these elements, under the influence of more southerly environments, there arose in time diversified culture groups, such as are now under investigation in various parts of the continent. We can not but admit, however, the plausibility of the theory that seafaring wanderers from other lands have now and then reached American shores, bringing with them the germs of distinct cultures, and, further, that the characteristic art phenomena of certain centers of progress are such as to give countenance to this idea. This is a most interesting and important branch of archeological research, and one with which archeologists must at this stage particularly concern themselves.

Archeology furnishes a vast amount of interesting data regarding the states of culture of the American race, but we note that in all the researches so far conducted no traces of culture phenomena have been found which extend below, on the one hand, or above, on the other, the range observed among the living or historic tribes. There is nothing so unique that it might not belong to known tribes or their immediate ancestors. It has been sought to differentiate a paleolithic culture and period in America, but without tangible result. So far

as the use of the terms "paleolithic" and "neolithic" are concerned they may both be omitted from the nomenclature of American archeology without loss, if not to possible advantage. The simplest forms of stone implements occur everywhere in association with the most highly developed forms, and neolithic forms are reported from formations of nearly all periods back to the earliest that have been observed.

In America, especially North America, we have sought almost in vain to establish a definite chronology of man and culture. Evidence of antiquity is not wanting, but when we try to adjust the phenomena to the geological time scale we meet with indifferent success. Hundreds of ancient caves have been searched, with only negative results; glacial gravels have been examined with great care, but the returns are exceedingly meager; river terraces and kitchen-midden deposits yield nothing of particular value, and the results, when viewed as a whole, instead of enlightening the mind, fill it rather with confusion. It is within the bounds of possibility that this confusion may in a measure be due to the presence in America of an autochthonous race element.

The contributions of American archeology in this department are not to be compared with those of the Old World, where definite chronological results are forthcoming on all hands. That America may yet furnish contributions of importance in this branch of inquiry, however, lies well within the bounds of possibility.

It is thus seen that there are in America numerous questions awaiting solution, and there is vagueness in many places; but, notwithstanding this, the results of our archeological investigations are on the whole most gratifying. Each year the areas of the uncertain and the unknown are being reduced, and when the results achieved are supplemented by the rich materials derived from the study of the living peoples they must go far toward illuminating the pages of the story of humanity in general which the Old World has been gradually but surely revealing.

Viewing the whole field of prehistorical research, we are struck by the fact that the past of man is rapidly disclosing itself to our vision, so that presently we shall be able to look backward through the biological and cultural vistas of his coming and connect the present with the vanishing point of the human perspective with an insight and comprehension little dreamed of until now.

EXCAVATIONS AT GOURNIA, CRETE.[a]

By Harriet A. Boyd.[b]

INTRODUCTION.

There is a land called Crete in the midst of the wine-dark sea, a fair land and a rich, begirt with water, and therein are many men innumerable, and ninety cities.—Odyssey, XIX, 172, Butcher and Lang's Translation.

The high expectations which scholars held of the good that would come to archeology through systematic excavations in Crete have not been disappointed. It is still too early to estimate the full value of the excavations which have been made by the British at Knossos,[c] Psychro,[d] Praesos,[e] Zakro,[f] and Palaiokastro,[g] by the Italians at Phaestos[h] and Aghia Triadha,[h] and by the American Exploration Society at Gournia. Enough has been unearthed, however, in the last four years to revolutionize our ideas of the state of culture attained by the Cretans of the "golden age" during the third and second millenniums B. C., and to lay surer foundations for the study of European civilization than ever before existed. Further work will no doubt bring many fresh surprises and will throw new light on the origins of Mediterranean culture.

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[a] Report of the American Exploration Society's Excavations at Gournia, Crete, 1901–1903.

[b] An abstract from transactions of the department of archeology, University of Pennsylvania, Vol. I, pts. 1 and 2, 1904, printed by permission of the American Exploration Society.

[c] See articles by Mr. Evans on the Palace Site in British School Annual, 1899–1900, 1900–1901, 1901–2, 1902–3, and an article by Mr. Duncan Mackenzie on the Pottery of Knossos in Journal of Hellenic Studies, 1903.

[d] See article by Mr. Hogarth in British School Annual, 1899–1900.

[e] See article by Mr. Bosanquet in British School Annual, 1901–2.

[f] See article by Mr. Hogarth on Excavations in British School Annual, 1900–1901, and article by Mr. Hogarth on Zakro Vases in Journal of Hellenic Studies, 1902.

[g] See article by Mr. Bosanquet in British School Annual, 1901–2.

[h] See article by Mr. Halbherr and Mr. Pernier in Monumenti Antichi della Reale Accademia dei Lincei, Vols. XII, XIII, and XIV.

The great palaces at Knossos and Phaestos complete each other architecturally, the former giving an elevation of three or even four stories, the latter furnishing a ground plan "simple and grandiose," as it has been called by Mr. Evans. In both we see the houses of rich princes who loved luxury, who patronized the arts of builder, sculptor, and painter, and used the talents of the scribe as well. The smaller finds at Knossos and Aghia Triadha by their variety and number give us a fuller knowledge of this prehistoric civilization than we have of many a later stage of culture, but of this, as of most subjects which deserve any investigation, the more we know the more we want to know. Palaces and tombs are not sufficient; we want also the homes of the people, for without an insight into the life of "the many" we can not rightly judge the civilization of any period. By a singular chance a well-preserved town, dating from the earlier period of the Great Palace at Knossos (about 1800-1500 B. C.) and containing a large quantity of tools, pottery, and other articles of daily use, has been brought to light by the excavations of Americans ("people of the great democracy," as Cretans call us) at Gournia, on the north shore of the isthmus that connects the east end of the island with the rest of Crete. It is not rash to suppose that this is one of the ninety cities mentioned by Homer in the famous passage of the Odyssey quoted above.

THE ISTHMUS.

Strabo, in Book X, Ch. IV, 3, of his Geography, describes the long, narrow island of Crete, with its northern coast line indented by deep gulfs, which at two points reduce the island to less than half its average width. At the Isthmus of Hierapetra, which is the eastern of these two points and the narrowest portion of the island, the northern and southern shores lie but 60 stadia (12 kilometers, about 8 miles) apart. Here nature has made the communication between sea and sea not only short, but easy, by leaving a narrow strip of lowland between the mountain ranges of Dikte in Sitia and Dikte in Lasithi (the legendary cradle of Zeus), a break in the long chain that forms the backbone of Crete. East of the isthmus an almost vertical rock wall of mountains hides from view the summit of Aphendi Kavousi, which dominates Sitia (1,472 meters, or about 4,829 feet), while across the valley to the west the land rises in more gradual ascent to mountain level, and from many foothills Aphendi Khristos[a] (2,155 meters, or about 7,070 feet), the loftiest peak of Lasithi, can be seen.

At the northeast corner of the isthmus, shut in by mountains on the east and coast hills on the west, lies the plain of Kavousi. In

[a] Aphendi Khristos is sometimes written Effendi Christos.

seasons of abundant rain like 1903 it gives good yields of olives, carobs, grapes, and grain; but in dry years like 1901 it is parched and fruitless. More fertile, because better watered, is the lovely valley of Kalo Khorio, which occupies the northwest corner of the isthmus, descending to the Gulf of Mirabello. Between Kavousi and Kalo Khorio[a] the coast, though utterly barren, is wonderfully beautiful. At Pachyammos there is a good beach; elsewhere steep cliffs, alternating with coves, form a coast line as picturesque as any in southern Europe, and within these coves rest waters as clear and rich in color as those of Capri. The main highway of Crete, connecting Sitia, Herakleion (Candia), Rethymo, and Canea, follows this coast and near Pachyammos meets the road that crosses the isthmus from Hierapetra. Since the earliest times this isthmus road must have been in constant use, for no other route across the island is so short, so level, so direct. Halfway between the two seas stands Episkopi, and side roads lead east to Monasteraki, Kato Khorio, and Apano Khorio, at the foot of the Thriphte Range, and west to Vasiliki and Kentri, situated on low hills. From Episkopi south the lowland widens, and, being watered by mountain streams, is richly productive of lemons, oranges, figs, and mulberries, as well as of the commoner fruits and grains. This cheerful fertility continues until the neighborhood of Hierapetra is reached, a region as barren as the northern shore and far less interesting.

From time immemorial the isthmus has been inhabited, and yet it is an interesting fact that with the exception of Hierapetra, where the modern city is built above ruins of Hellenic and Roman cities of the same name, the sites occupied at different periods are distinct[b] one from another. Men of the bronze age chose low hills not far from the sea; their successors, a ruder people of the iron age, had strongholds on almost inaccessible mountain heights; Greeks and Romans established trading stations on the shore; Venetians and Turks built watch towers and block houses at commanding points for the purpose of holding the unfortunate Cretans in subjection; modern Cretans still prefer the security of the hills, but a seaward movement has already begun as a result of the peace and order that since the liberation of Crete in 1898 have prevailed throughout the island. * * *

My first year's work on the isthmus of Hierapetra as Fellow of the American School of Classical Studies at Athens has been described in an article entitled "Excavations at Kavousi, Crete, 1900," published in the American Journal of Archeology, second series, Volume V, 1901, pages 125–157. Opportunity for a second campaign was given

[a] Καλὸ(ν) Χωρίο(ν), beautiful village, is aptly named.

[b] Azoria Hill may be an unimportant exception to this rule.

me in 1901, when the American Exploration Society, of Philadelphia, offered to support further researches in Crete. Mrs. Cornelius Stevenson, secretary of the society, actively forwarded the enterprise, and Mr. Calvin Wells, of Pittsburg, and Mr. Charles H. Cramp, of Philadelphia, generously contributed the necessary funds. My colleague in 1901 was Miss B. E. Wheeler, of Concord and Providence, one of my classmates at Smith College. Miss Wheeler and I landed in Crete April 7. Much progress had been made at Knossos and Phaestos, and such success in the Mycenæan and pre-Mycenæan field, or, to use more up-to-date nomenclature, the "Minoan" field, increased our longing to find something belonging to this golden age of Cretan history.

We made a round trip through Chersonnesos (a Greco-Roman city), Neapolis (the town from which one visits a difficult iron-age site at Anarlachos and the Hellenic Deyros), Olunta (ancient city Olus, near which lie remains probably prehistoric), Gonlos (site of the ancient city Lato and of an important prehistoric settlement), Kavousi, Episkopi, Mesoleri (ancient Oleros), Kalamavka (reserved by British as a prehistoric site), Mallais (Homeric Malla), Psychro, and back to Herakleion. On this trip we saw nothing more promising than our clue at St. Anthony's and the Cyclopean wall at Avgo, and as Miss Wheeler was willing to try a second year's luck on the isthmus of Hierapetra, we informed the Government of our wish to renew work in that region. The St. Anthony clue was too slight to be mentioned save between ourselves, and when we returned to Kavousi presumably to find geometric or at best sub-Mycenæan things, our quest excited pity rather than envy among the archeologists at Herakleion.

We went directly to Avgo to learn the nature of the megalithic structure near the Chapel of the Virgin. Avgo Valley is so overshadowed by the surrounding mountains that the sun does not reach it until late, and the mornings and evenings are very cool. Consequently the peasants live here only in summer and content themselves with one-room stone huts without windows.

For two weeks our party living in these huts suffered some hardships, especially during thirty-six hours of incessant rain that caused serious floods in eastern Crete, wrecked a hut near us, loosened our own walls, and poured into the hut we used for a kitchen. The results of our excavations at Avgo were meager.[a] On holidays and on days when the ground was too wet for digging we rode up and down Kavousi plain and the neighboring coast hill seeking for the bronze-age settlement, which I was convinced lay in

[a] See Transactions Department of Archeology, University of Pensylvania, 1904, pp. 18–20.

these lowlands somewhere near the sea. It was discouraging work, for my eyes soon came to see walls and the tops of beehive tombs in every chance grouping of stones, and we went to many a "rise of ground which at a distance looked a perfect Mycenean hill, but proved to be all rock. From an archaeological, as well as an agricultural, point of view the curse of the Kavousi region is the shallowness of soil; even at Gournia we often have occasion to bemoan it. At last the rumor of our search reached the ear of George Perakis, peasant antiquarian of Vasiliki, a village 3 miles west of Kavousi, and he sent word by the schoolmaster that he could guide us to a hill three-quarters of a mile west of Pachyammos, close to the sea, where there were broken bits of pottery and old walls. Moreover, he sent an excellent seal stone picked up near the hill, and although seal stones are not good evidence, being easily carried from place to place, his story was too interesting to pass unheeded. Accordingly, on May 19, Miss Wheeler and I rode to the spot, found one or two sherds with curvilinear patterns, like those from St. Antonys; saw stone in lines, which might prove to be parts of walls (never more than one course visible), and determined to put our force of 30 men at work there the following day. Three days later we had dug 19 trial pits and had opened houses, were following paved roads, and were in possession of enough vases and sherds, with cuttlefish, plant, and spiral designs, as well as bronze tools, seal impressions, stone vases, etc., to make it certain that we had a bronze-age settlement of some importance. Accordingly, I sent the following cablegram to the American Exploration Society, which was received in Philadelphia four days after the first visit paid by me, or, as far as I can learn, by any archeologist to the site of Gournia: "Discovered Gournia—Mycenean site, street, houses, pottery, bronzes, stone jars." We immediately petitioned the Cretan Government for special permission to excavate this new site for the American Exploration Society of Philadelphia, and our request was promptly granted.

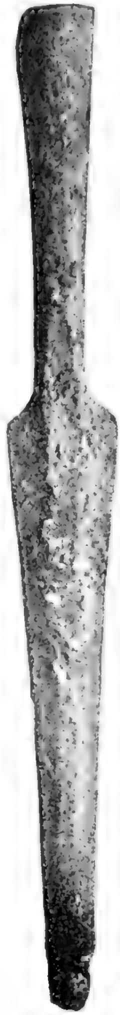


FIG. 1.—Bronze spear head. First "find" at Gournia, May 20, 1901.

Gournia is a name given by the peasants of the district to a basin opening north on the Gulf of Mirabello and inclosed on the other three sides by foothills which rise west of the narrow strip of isthmus. For one-half its length from south to north this basin is divided into two narrow valleys, of which the western forms a broad torrent bed,

dry in summer. The southern end of the ridge was used in Greco-Roman times, for here in the chapel of Aghia Pelaghia is a stone bearing the inscription "Klythos made (it)," and close at hand graves have been discovered containing Roman vases. This end of the ridge being for the most part an irregular mass of limestone, is suitable, perhaps, for burial, but not for habitation. Farther north the ridge becomes less rugged; platforms of earth are upheld by rock ledges; there is a slight dip, and we stand on the acropolis of the ancient city, every foot of its summit and slopes covered with roads and dwellings. But the rock reappears at the northern point of the ridge, beyond which the valleys meet and extend in one plain to the sea. The eastern valley and a small part of the plain can be cultivated, but hills and shore bear no crops except stones and low carob trees. The rugged character of the ridge and the dense growth of carobs which covered it made it possible for the acropolis to escape the notice of passing archeologists, although many had traveled along the important highway from Herakleion to Sitia, which actually crosses the lower part of our site and lies within one-eighth of a mile of the acropolis itself. The higher hills south and southwest of Gournia are composed of pudding stone, which easily breaks off in shallow caves, while the lower hills are of limestone, like the ridge.

Our town, which until we know its ancient name must be called by the modern designation Gournia, covered not only the middle of the ridge, where it rises 200 feet above sea level, one-quarter of a mile back from the gulf, but extended across the eastern valley up the hills to the east and northeast, so that the acropolis was the center of a settlement of considerable size. To-day the nearest harbor is at Pachyammos, a small coast-guard station three-quarters of a mile east of Gournia. This place seems destined to grow to an important port. An excellent road, built by French soldiers during the recent international occupation of Crete, connects it with Hierapetra, on the south coast, only 8 miles distant, and this land connection between the two seas across the narrowest portion of the island is preferred to rounding Sitia, where storms are frequent and severe. The line of the north shore has changed, and it may be that in early times the harbor lay in an arm of the sea directly north of Gournia. At all events, the sea has here encroached on buildings which are proved by construction and by contents to be of the same period as those on the ridge. From this group of buildings a road probably led up to the low acropolis, and on reaching the middle eminence must have met a road which we have found continues on both the east and west sides of the hill, rising by steps where the slope is steep, and conducting the traveler at length to the small palace of the local governor.

At the beginning of excavations only a few stones showed above the surface and many houses were entirely hidden, being discovered in

SKETCH PLAN OF THE CENTRAL ACROPOLIS, GOURNIA, CRETE.

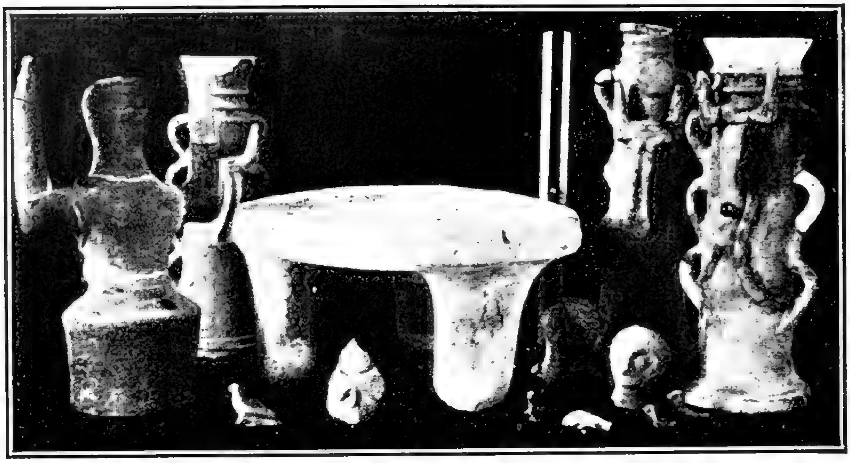


FIG. 1.—OBJECTS DISCOVERED IN MYCENÆAN SHRINE.

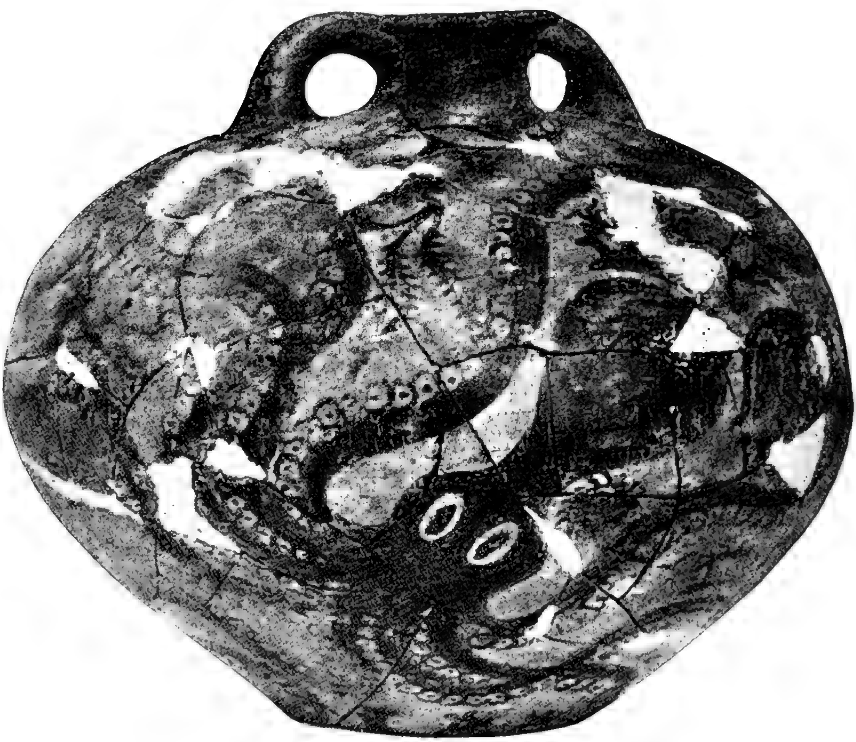


FIG. 2.—OCTOPUS VASE.

OBJECTS EXCAVATED AT GOURNIA.

the course of digging by workmen who, following the roads, came upon their thresholds. The upper parts of the houses had fallen long ago, covering the hill with their ruins. On the top of the hill, where denudation is constant, there was but a scant covering of earth over the native rock; here some of the best objects of bronze and terra cotta were found within 50 centimeters of the surface, and, indeed, at certain spots, which we now know to have been within dwellings, the native rock lay bare. On the sides of the hill where earth accumulates we were often obliged to dig 4 or 5 meters before reaching virgin soil, live rock, beaten floor, or stone paving, as the case might be.

Excavations have been carried on at Gournia through two campaigns, May 20 to July 2, 1901, and March 30 to June 6, 1903, with a force of 100 to 110 workmen and about a dozen girls who wash potsherds. Unfortunately, Miss Wheeler could not leave America in 1903 to give her efficient aid toward the accomplishment of the work which we had started and planned together; but I was ably assisted in the second season by Mr. Richard B. Seager, who took special charge of the pottery as well as helping in the field. Miss Moffat, of Northampton, Mass., left a Paris studio to accompany the second year's expedition, and has made for the American Exploration Society a series of excellent colored drawings of some of the better vases and scores of drawings to scale of the commoner pottery, saving thereby many shapes which, through the inferiority of the common clay, would have been lost. I consider these drawings and others executed for us by the Danish artist, M. Bagge, among the most important contributions which have been made to archeology by our expedition.

The brief survey of results to be given here is strictly provisional, and will, I hope, be superseded by a more careful study of the work when the excavations at Gournia shall have been completed.

THE TOWN AND ITS BUILDINGS.

The sketch plan reproduced in the accompanying illustration, begun in 1901 by Mr. Fyfe, of Glasgow, architect for Mr. Evans at Knossos, and finished by me in 1903, with the help of Mr. Harold Hastings, gives a better idea of the town than words can. As the squares measure 20 meters on a side, the entire area cleared may be roughly computed as 2 acres, the top of the acropolis as about 1 acre, and the palace as one-third of an acre. Thirty-six houses and parts of several others are uncovered.

The roads of Gournia have an average width of about 1.60 meters and are paved with stones which seem to have been chosen from near the sea, and which, worn first by the sea and then by the passing of many feet, present a fairly smooth surface. They are laid with care, not actually fitting, but leaving no such ruts and holes as are

seen in Cretan roads to-day. Where the roads ascend we find flights of steps as in modern Naples; the longest flight is in the road that climbs the east slope.

Gournia houses are superior to any homes of bronze age people found on the Greek mainland. Their lower courses are of rubble, but often considerable care is taken in the choice of stones, and they are roughly aligned. The size of stones varies greatly—certain walls on the east slope of the hills being sufficiently massive to have suggested on first discovery fortification walls, but as further digging disclosed massive and weak walls side by side, we came to the conclusion, in which all who have visited the site agree, that the heavier construction belongs simply to the better-built houses and that the place is unfortified. The width of the house walls varies from 50 to 90 centimeters, 60 centimeters being the average. That the upper walls of many of the houses are of brick is abundantly proved. These bricks average 40 by 30 by 10 centimeters, and seem to be fire baked. Before May, 1901, only sun-baked bricks, or those accidentally burned by conflagration had been found in bronze age settlements in the Ægean; but almost simultaneously at Zakro at the extreme east end of the island, where Mr. Hogarth was conducting successful excavations, at Avgo, and at Gournia fire-baked bricks came to light in May, 1901, and they have since been found at Palaiokastro. The clay is coarse and unevenly baked, but the bricks retain their shape well. Bricks were used not only in upper walls, but also in partitions—always on a stone base. In a house on the east slope we found partition walls made of mud, which, after drying in the sun, was overlaid with plaster, a careless construction not uncommon in modern Greek villages. The marvel is that such flimsy work should have remained sufficiently intact for thirty-five hundred years to be immediately recognized and preserved by the workmen who dug it out.

Plaster is employed extensively on the door jambs and on the walls, both outer and inner, overlaying stone and brick. It is of several varieties, a coarse white kind and a gray pebbly sort being commonest. In some instances a coarse plaster covers the wall and a second finer layer covers this, the color of the finer layer being usually a very light bluish gray, although we have a few precious bits of brighter stucco of a shade somewhat deeper than the Pompeian red. In one of the western storerooms of the palace we found two small curiously molded pieces of stucco, one shaped as a thunderbolt and the other as a swallow; these have one flat surface, as if they might have formed ornaments in relief on the wall.

Doorways are carefully made with stone sills and bases for the jambs, which were in rare instances of stone covered with plaster, sometimes of wood, often of brick clay plastered over. A shapeless

mass of bronze, evidently reduced by heat, lay in a doorway of the palace, and may have formed a part of the trimmings of the door. As a rule the house walls are not sufficiently high for windows to have been preserved, but three openings in walls on the east slope were certainly intended to admit light and air. Floors were made of beaten earth, "terrazza" (a cement of pebbles covered with a layer of plaster), stone slabs, or paving stones like those in the roads. As for roofs, the evidence seems all in favor of the flat terrace forms common to-day in the East. Pieces of plaster still bearing impressions of reeds show what the ceiling must have been. In a ground-floor room of the palace a large tree trunk was found fallen and burned, completely charred through, but retaining its original shape; this supported either the flooring of the upper story or the roof. The central hall of the palace was choked with such timbers.

In plan the houses are simple, conforming to the lay of the land rather than to a fixed form. When similarity of plan can be detected, as in certain houses on the east slope, the arrangement is modern rather than classical and is in agreement with the mosaic pictures of Minoan houses found in the palace of Knossos in 1902. As in the mosaic, so at Gournia we see the houses built flush with the streets and usually provided with a good stone threshold; crossing this we enter a paved antechamber with doors leading to the ground-floor rooms and steps mounting to the second story; cellar steps may descend directly from the antechamber or from an inner room. Certain cellar rooms are finished in plaster and provided with doors; others were entered, if at all, by ladders from above and can have served only for storerooms; still others were mere substructures. Several houses on the east slope have open courts which seem to have been generally omitted in the private dwellings on the top of the hill for lack of space. We know that there were second stories, because five stone staircases are well preserved and the former existence of wooden steps at many other points is clearly indicated. Moreover, many objects, and these usually the best, were found in the earth at varying heights above the floor level, and except where there was proof that these had stood on a wooden shelf, since rotted away or burned, they must have fallen from an upper story.

No satisfactory explanation has yet been given for a stone object which is very often found just within the street door. It looks like a large mortar, and either stands upon the paved floor or is sunk beneath it to the rim. It would make an awkward basin, for there is no way of removing water except by dipping; on the other hand, its position, invariably close to the outer door, makes us think that it must have served some other purpose than the one of pounding and grinding which its form suggests, or at least that some special significance was attached to its use. No pestle has yet been found with

it, although smaller pestles and mortars are among our commonest finds.

Special mention should be made of the palace. On the west side are four storerooms communicating with a flight of steps, and three long, narrow magazines opening on a common corridor that correspond, though on a much smaller scale, to those at Knossos and Phaestos. The rooms south of these magazines were reached by a staircase, of which the steps are destroyed, but a transverse supporting wall still remains. West of the storerooms the road widens into a small plateia, of which we have not yet determined the western boundary. South of this is a space, having a cement pavement, which seems to be part of the palace, possibly a loggia, in which case the west road continuing south must have formed a covered way within the palace. From the southern end of this covered way a paved passage leads east, while the road continues southwest. The eastern passage ends in three steps ascending east and a return series of two steps which communicated with the building south of the passageway. Beyond the three steps is a large open court, which seems to answer to the west court of Knossos, and may have served as a market place for the town. This court was paved with cement; its eastern and southern limits are not yet reached. As we turn north from the steps we see on the left running north for a distance of 5.60 meters a stylobate, on which stood two square pillars, measuring 85 centimeters on a side at the base, with shafts about 20 centimeters less in dimensions. Of the southern pillar nothing remains, but its position can be distinctly traced on the stylobate; of the northern pillar we still have the base and lower part of the shaft. The profile of the base is carefully cut.

Fig. 2.—Sacred horns (coarse terra cotta).

Beginning March 30, 1903, at this portico, from which we had removed our last loads of earth in 1901, we dug northward into the center and, as it proved, the most interesting part of the palace. In the northwest corner of the court we came upon two low flights of steps at right angles to each other, which reproduce the arrangement at Knossos and Phaestos. Within their angle a pair of sacred horns, fashioned in coarse terra cotta, measuring 0.38 centimeter across and 0.38 centimeter in height, lay as if fallen from above. The flight of

steps leading west gives access to the interior of the palace. Without trying for the present to explain a huge single block of stone near the top of the steps that may have been the floor of a bath, we may turn northward, cross a threshold 1 meter wide and 2 meters long, and following a corridor that runs first west and then north, enter an inner court paved with cement ("terrazza") and open to the sky. The west side of this inner court was formed by a line of storerooms mentioned above, which lie on a somewhat lower level; north of the court are more storerooms, a corridor leading to the west entrance of the palace, a well-preserved bath, and a small staircase to the second story. On a step of this staircase stood a three-legged stone basin, too heavy to be saved by the owners or easily looted by an enemy.

The east side of the inner court opens through a portico composed of two square pillars alternating with two round on a square hall, which was certainly covered, as it was choked with fallen timbers, masses of plaster, and stone slabs that in Minoan houses, as in many Italian houses to-day, made the flooring of the second story. In the southeast corner of the hall is a rectangular recess with a stone bench around three sides and a round base for a column that must have supported an architrave across the open side. Here we may suppose the prince sat to receive his friends and to dispense justice. It is a semipublic part of the palace, corresponding to the throne room at Knossos. No doubt the private rooms were on the second story. To them a narrow flight of stairs led from the northeast corner of the hall. The walls of this hall are carefully built of well-squared blocks of soft limestone, like those used in the more important parts of the outer walls of the building. At first we were astonished to find immediately adjoining this important hall on the north one square and two oblong storerooms, the square room containing 12 huge pithoi, one of which is still perfect; but reflection shows that this arrangement is a good one, for if the hall was semipublic and was an eating hall for retainers it would be convenient to have "cellar" and pantry at hand.

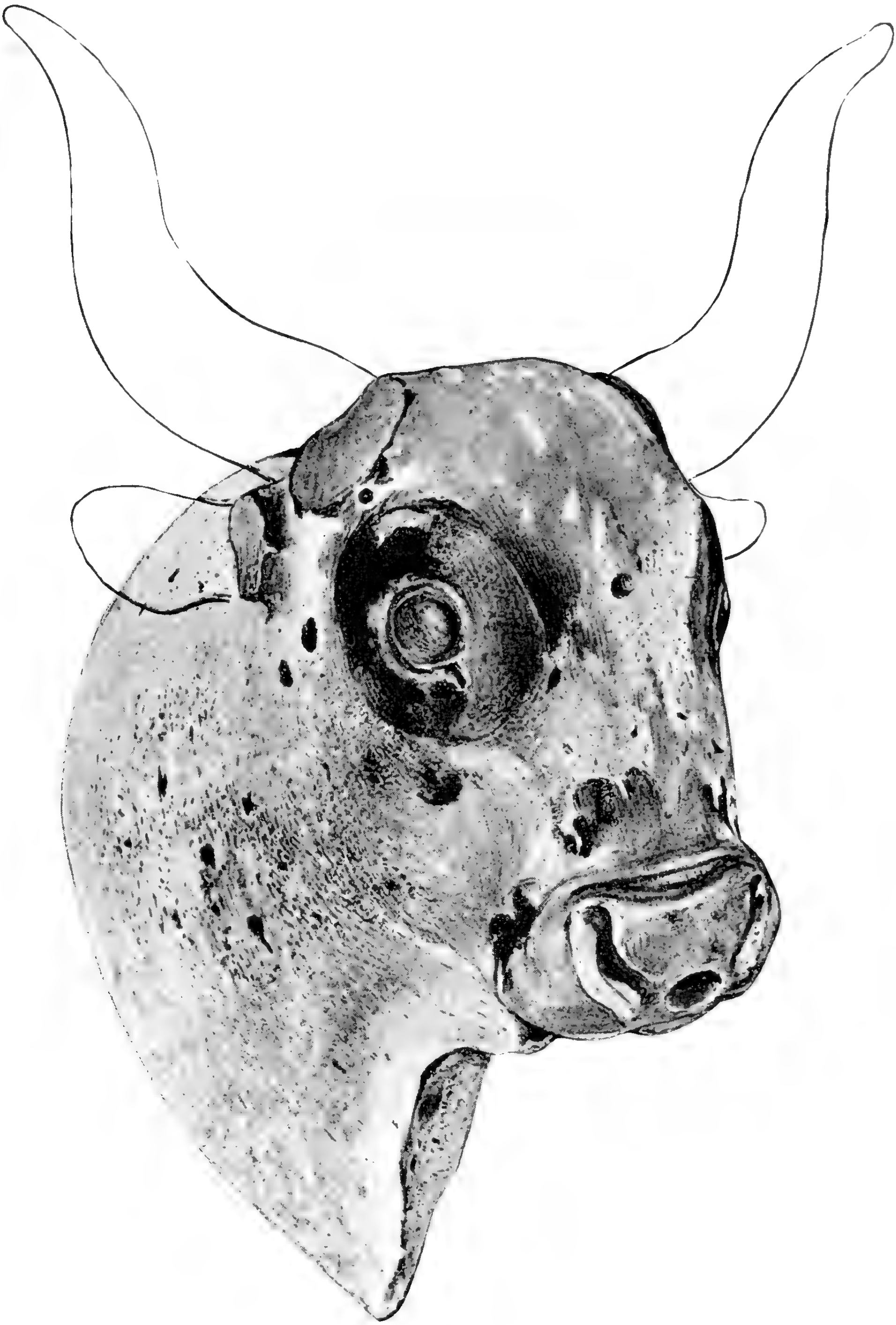
A part of the hill was cut away to give a level floor for the hall and the adjoining rooms, and on the east the ground lies 6 or 8 feet higher. Here on the top of the hill no soil could accumulate to protect the ancient structure, and a careful scouring down to live rock simply proved that there had been nothing lower than the second-floor level between the hall and some narrow rooms of "magazine type" on the extreme eastern limit of the palace, where the land again descends, and that of the second story not even a vestige remains. To the south of the palace, as here described, lies a building of many rooms, which may form a southern wing (possibly the women's quarters) or may be the beginning of a block of houses. It

contains a bath with cement floor and stuccoed wall, on which traces of red and yellow color are still visible, a small square court, several storerooms, and a deep cistern with water channel.

In all the more important parts of the palace squared blocks of soft limestone take the place of rubble; usual dimensions about 1.40 meters long, 90 centimeters wide, and 60 centimeters high. One block attains the length of 2.10 meters. These blocks are carefully trimmed on all sides, and are laid in a thin bed of clay, each course receding about 10 centimeters from the one below it. The outer face was covered with stucco, and we have some traces of its use on the inner walls also. On a block near the southwest corner the double ax of Zeus is carved, as at Knossos and Phaestos. We note also many reentrant angles, a feature of Cretan architecture of this period.

Of the shrine which lies in the center of the town, approached by a well-worn road of its own, I shall say very little, as it opens up too large a subject for discussion here. Not imposing as a piece of architecture, it is yet of unique importance as being the first "Mycenæan" or "Minoan" shrine discovered intact. The worshiper ascended three steps and, through a doorway 1.50 meters wide, entered an inclosure about 3 meters square, surrounded by walls half a meter thick and 50 to 60 centimeters high. The floor is of beaten earth. Lying near the top of the hill, our shrine has suffered much from the forces of nature. A wild carob tree growing within its bounds had partly destroyed and partly saved its contents, of which the more noteworthy are a low earthen table, covered with a thin coating of plaster, which stands on three legs and possibly served as an altar; four cultus [a] vases bearing symbols of Minoan worship, the disk, consecrated horns and serpent, a terra-cotta female idol entwined with a snake, two heads of the same type as the idol, several small clay doves and serpents' heads, all of coarse terra cotta, and a fragment of a pithos, on which a double-ax and disk are modeled in relief. These were huddled together in the northeast corner; the rest of the shrine was entirely empty of finds, and nothing stood in the recess at the southwest corner, although this seems to correspond to the shelf in the shrine more recently discovered at Knossos, on which were found many offerings.

[a] I have called them "cultus" vases, and such I do believe them to be in spite of Wide's article on Mykenische Götterbilder, in Idole Athenische Mittheilungen, XXVI, 1901, pp. 247–257, in which he calls similar objects from Prinia "idols." These resemble ring stands found in Egypt, and with their slightly flaring rims would conveniently hold bowls. Objects with the same rings, flaring bases, and flaring rims have been found at Orchomenos and elsewhere in Greece and the islands, but none of this height. The Gournia vases are furnished with two opposite sets of upright loops, with an upright handle between them.



BULL'S HEAD.

Length of head 12 cm., width across forehead about 0.07 cm. Hollow with a flat back, as if to fit against a wall, 14 cm. long by 9½ cm. wide. The gray clay is medium fine, and even seems to have been covered in greater part with a shining white slip, as if to imitate silver, touched up with black and in certain places with a red pigment. Well modeled. A hole, depth 0.8 cm., in the end of the nose; second hole, depth 2 cm., in top of head. Horns and eyes broken.

Of tombs we have as yet found no trace at Gournia, although vigorous search has been made for them, but we have signs of intramural burial on the north spur of the acropolis, where within an inclosure resembling a house we uncovered the bottoms of three casellas (average length 1 meter), together with many human bones, three bronze knives, and a thin tip piece of beaten gold, without pattern, as large as the end of a thumb. Fragments of two other casellas were unearthed about 7 meters north of this point. But on this north spur of the acropolis the soil is never more than 30 centimeters deep, and this readily explains why of the casellas only the bottoms and 5 or 6 centimeters of the sides were preserved, why the bones were scattered, and why no more objects were found with them. Within the north room of house 6 on the west road, 1 meter below the surface, we came upon a better preserved casella decorated with a link pattern of debased type, and close to it a grotesque mourning female figure in coarse terra cotta similar to figures found in Cypriot tombs. I believe that these objects were deposited in this house at a period distinctly later than that of the settlement itself, and it may be that the casellas on the north spur are also late, although too little remains to establish a proof.

February, 1904.

ARCHEOLOGICAL RESEARCHES ON THE FRONTIER OF ARGENTINA AND BOLIVIA IN 1901–02.[a]

By Eric von Rosen,
Stockholm.

In the spring of 1901 an expedition left Sweden, under the leadership of Baron Erland Nordenskiöld, for the Argentine Republic and Bolivia. Of that expedition I became a member, for the purpose of carrying on archeological and ethnographical research. Time does not admit of my sketching here the course of the expedition, and that is the less necessary as Baron Nordenskiöld has already published several essays in which an account of its doings has appeared; I at once, therefore, pass on to describe the archeological results I was able to obtain during the progress of the expedition.

About 3,500 meters above the sea, at the foot of the chain of mountains that border on the west the lofty plain of Puna de Jujuy in northern Argentina, a farm, Casabindo, is situated. The district round, now desolate and almost desertlike, was nevertheless at one time inhabited by numbers of people. Evidence of that fact exists in the very numerous remnants of huts, corrals, and irrigation terraces. These monuments of a by-gone civilization have long been known to exist, and Doctor Uhle visited the place on one of his journeys, yet, save for Doctor Lehmann-Nitsche's Catalogue of the Puna Collection in the La Plata Museum and some statements in Ambrosetti's essay, entitled "Antiguedades Calchaquies," nothing has up to the present been published relative to Casabindo.

About 1 kilometer north of the farm there are some heights, formed of a tolerably loose species of rock resembling sandstone. Owing to weathering and the effect of the wind, grottolike excavations of varying dimensions have been formed in the rock in the process of time; many of these grottoes have in earlier times been used as burial places. On plate I, figures 1, 2, we see photographs of one of

[a] A preliminary report dedicated to the Fourteenth International Congress of Americanists, at Stuttgart, 1904. Reprinted from author's copy.

those grottoes, showing, in the corner, a skeleton which I unearthed. The grottoes average about 1.5 meters in depth and about 2 meters in height at the entrance. The rock forming the foundation of the grotto slopes usually downward from the entrance, but rises again farther in, so that a longitudinal section shows that the floor, the inner wall, and the roof of the grotto together form a curve which nearly approximates to two-thirds of the circumference of a circle. Thus the floor of the grotto is markedly concave in form; it is covered with a layer of sand, usually of a depth of as much as one meter at the deepest part. In that layer the corpse is found deposited in a sitting posture, or else, where there was not a sufficient depth of sand, in a lying one, but always with the legs bent up and pressed upon the chest, so that the chin and knees almost touch. I have not observed that the corpse was systematically placed facing any particular point of the compass. In front of the entrance to the grotto there is often to be seen a semicircular arrangement of stones, piled in several courses, one on top of another; that was presumably a precautionary measure against the removal of the sand by the blowing of the wind. As a rule, I found only one skeleton in each grotto, but in some there were up to the number of three. In some graves the dead had household utensils, etc., lying beside them, though in only one of the graves which I examined was there any trace of clothes. As the layer of sand in the graves has never been exposed to the influence of any damp to speak of, a number of the corpses, instead of rotting away, have merely dried up; they resemble mummies in appearance. It seems to me scarcely probable that any species of embalming was resorted to; it must, indeed, have been superfluous, inasmuch as the articles of wood and other perishable or destructible substances which I found in the grottoes are in remarkably good preservation.

I succeeded in collecting a fairly large number of specimens of skeletons, both of adults and children. Professor Retzius is at present studying them, and he informs me that all the heads from here bear evidence of having been artificially deformed to a greater or less extent. The hairs upon them are coal-black, coarse, but not very stiff. Round one of the heads there was a curious bandage of llama wool. The body to which this skull belongs was wrapped round in two woven mantles, one of a very delicate texture, worked in a strange pattern and of an exceedingly pretty color; the other coarser and very thick. The finer one is probably of vicuna wool, and was woven in a peculiar manner, whereby the threads were made to follow the pattern. Consequently the threads in some places are very closely packed together, in others wider apart. The coarser mantle is of llama wool. Close to the skin of the dead body I found remnants of a garment of some thin material, originally white in color.

FIG. 1.—GRAVE GROTTO. IN LOWER LEFT CORNER OF THE GROTTO IS AN UNEARTHED SKELETON IN SQUATTING POSITION.

FIG. 2.—NEARER VIEW OF SAME GROTTO SHOWING SKELETON.

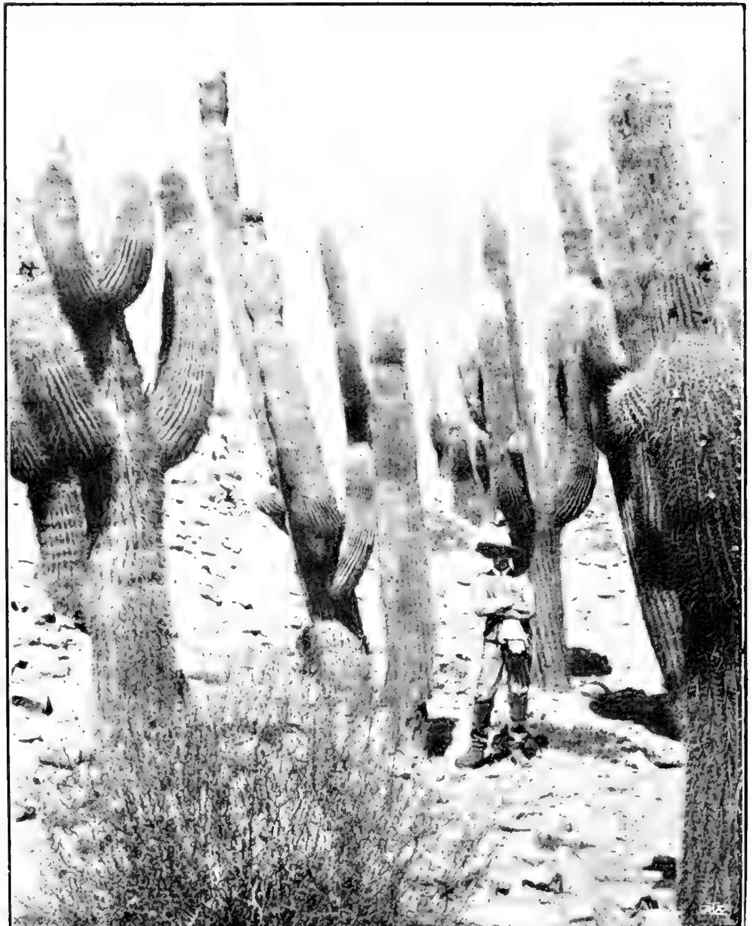


FIG. 1.—CACTI, PUNA DE JUJUY.

FIG. 2.—DOOR OF CACTUS WOOD, PUNA DE JUJUY.

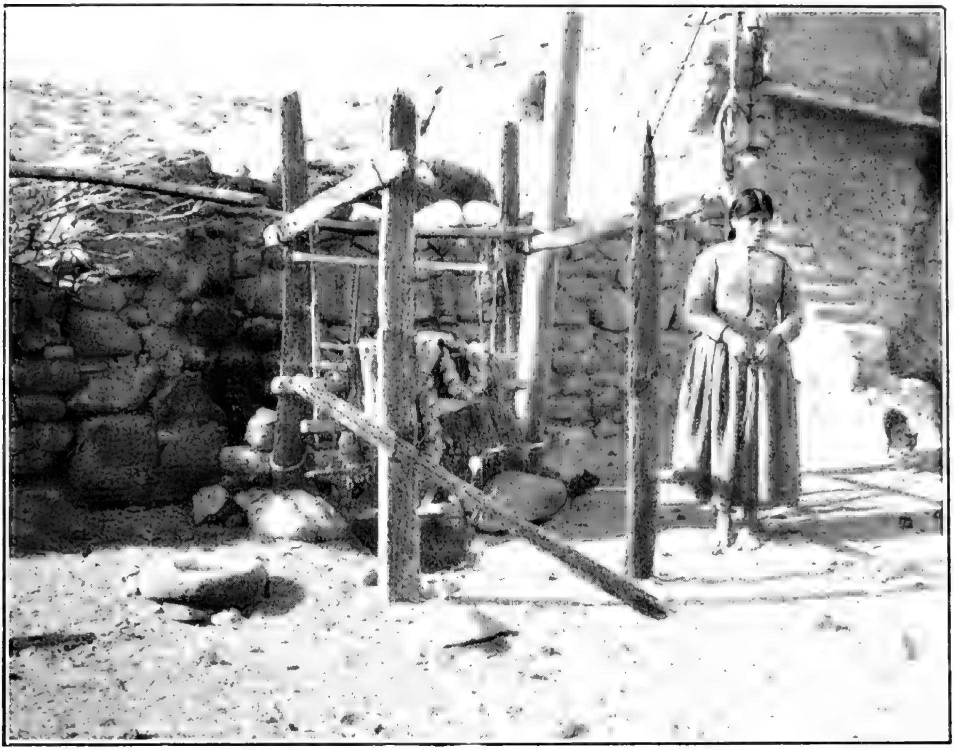


FIG. 1.—LOOM OF CACTUS WOOD, PUNA DE JUJUY.

FIG. 2—STONE HUT INHABITED BY PUNA INDIANS.

FIG. 1.—ANCIENT IRRIGATION TERRACES NEAR CASABINDO.

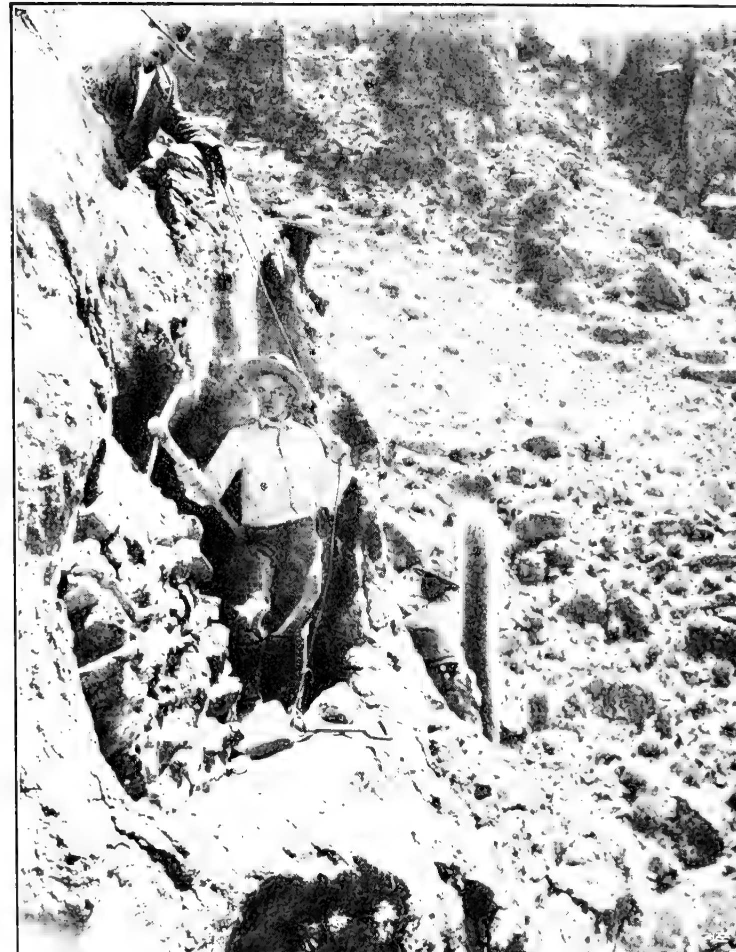


FIG. 2.—WALLED-UP GROTTO NEAR CASABINDO.

As already mentioned, in the majority of cases articles had been deposited in the graves with the dead bodies; as a rule these articles consisted of a bowl, some corncobs, and a cup, which at the time of the burial was probably filled with water, as is the custom to this day among the Chorotes Indians. Some graves, however, were more plentifully supplied with similar articles, as small cups of burnt clay, clay bottles with painted ornamentation, a small red clay bottle of a beautiful shape and of a fine material, a clay bowl with a handle in the shape of an animal's head. At the bottom of this bowl there is a black cross, painted, and with arms of equal size. Some corncobs were found in the bowl. In one grave two cups of exactly the same size and appearance were found, cut out of one piece of a hard kind of wood (pl. IX, fig. 3); the exterior is richly adorned with engraved ornaments. The discovery so far from the sea of some shells of marine mussels, probably used as spoons, is remarkable. In these graves were further found a bone case containing cactus prickles, used doubtless in tattooing, as is still the case among the Chorotes; an instrument flattened like a spoon at one end; some of the so-called llama bits. It is possible that the objects in question were actually used for that purpose, but if so I presume that they were not placed in the animal's mouth, but across its nose, for I have not been able to discover any trace of wear by the teeth on any of the numerous specimens I have come across. On one of the "bits" of the same description there is a rein of llama wool fastened to it.

Outside most of the grave grottoes I found that the sand for a somewhat limited area around was mingled with splinters of pottery, pieces of chipped stone, bones of animals, charcoal, etc. These collections of remnants of a bygone civilization each extended over an area of at the utmost 15 square meters; in places they were as much as one-half meter in depth. That dwelling places and graves were found so close together goes to show that the custom prevalent, for instance, among the Chiriguano Indians of burying the dead near their residences was general in this portion of the Puna, too. In the collections spoken of above I came upon some clay vessels of rather larger size than the generality. Besides splinters of pottery, chipped stone, charcoal, corncobs, and sundry bones of llamas, etc., I also found there arrow and lance heads, axes, spindle whorls, stone beads, etc. The axes or parts of axes discovered there were made of schist and were all of approximately the same type. One of the axes is about 15 millimeters thick and the edge has been sharpened on one side. Some of the other axes found there, however, had their edges sharpened on both sides. Ambrosetti and Lehmann-Nitsche describe implements of an exactly similar character, but they do not seem to have found any trace of the axes

having been provided with handles. I made the discovery, however, very soon, that the implement had had a handle, for on several of the specimens I obtained there were plain marks of friction against some hard object on one of the surfaces of the projecting part, which itself resembled a handle. On some of the axes is plainly to be seen that the wooden handle has produced a shallow, level furrow in the stone (pl. VIII, fig. 4). Subsequently I found in another grave a handle bent at an acute angle and shaped at one end for fastening the ax more securely to it. I placed one of the axes before described in contiguity to this handle, and thereby convinced myself that the worn surface on the ax very closely corresponded to the level surface of the handle; the two parts were probably united together by means of something wound around them or by being incased in leather. It is possible that resin or some other adhesive substance may have been employed to prevent the ax gaping; the fact of its having been insecurely attached is, however, amply proved by the considerable amount of wear shown on the handle.

The fragile material of which the ax is made renders it an impossibility that it can have been used for dealing with any hard substance; on the other hand, this ax would be an admirable implement for peeling off the soft exterior of the pillar cactuses, when the hard internal stem of the plant is to be got at. With the trifling exception of small bushes and the *Polylepis racemosa*, which resembles a shrub, and, moreover, occurs very sparsely, there do not exist any trees but the cactuses in the whole of the Puna that yield wood for manufacturing purposes or for fuel. These cactuses (pl. II, fig. 1) attain a respectable growth. The adaptability of the wood of the cactus for manufactures is shown both by the loom (pl. III, fig. 1) made of cactus wood and by the door (pl. II, fig. 2) of the same material.

About 8 kilometers northwest of Casabindo, in a narrow valley, there are numbers of remains of round stone huts. They are, indeed, so numerous that we may well assume that a population of several thousands dwelt here. Stone huts of a similar appearance are still used in the Puna, though only sparsely. The illustration (pl. III, fig. 2) shows a modern hut of the kind. The roof timbers are of cactus wood, covered with sticks and straw. The valley leading from Casabindo to the ruined city is hemmed in by fairly steep slopes, covered almost throughout with stone terraces of from 1 to 2 meters in height and of similar appearance to the irrigation terraces of the Inca period, which are so common in Peru. Plate IV, figure 1, represents a terraced mountain slope at Casabindo. Plate IV, figure 2, shows a small grotto, the entrance to which has been blocked up with a stone wall. Grottoes of that kind are of very general occurrence in the vicinity of the irrigation terraces. At the foot of the wall there

was a rectangular opening large enough for a man just to manage to creep through. A couple of walled-up grottoes of a similar character to this one were investigated by me, but they proved to be empty, and their object is a puzzle to me. Ambrosetti has described a grotto of the kind, but he, too, is unable to arrive at any satisfactory explanation of the use to which they were put, although he is inclined to consider them emptied graves.

Near the ruined city just mentioned I came upon an urn of burnt clay deposited in the ground and containing the dried-up corpse of a child with a deformed head. The mouth of the urn was covered with a clay plate turned upside down. The child had its sandals buried with it and a rattle, consisting of the fruit of the *Juglans australis* that grows in Chaco. A clay dish, containing some corncobs and a couple of bowls of pumpkin rind, had also been deposited in the urn. Beneath a projecting slab of rock, quite close to the above-described grave, I came upon another, containing several skeletons and numerous objects, as a clay vessel, a bowl of pumpkin rind, a wooden spoon, small spindle whorls of wood, an implement in the shape of a knife of some hard wood, a bar of wood with remnants of a fiber tie attached. The Chorotes Indians have an implement which they use for carrying fish about in and which in appearance exactly resembles this; further, a club or mallet, a diminutive club, a bow, a miniature bow, an ax handle, a miniature ax handle, a square slab of palm wood, and a bag of leather. This bag contained bars of wood that show evident traces of having been employed in kindling a fire. A more detailed account of the procedure, as observed among the present-day Chaco Indians, I propose to give in my lecture upon the Chorotes. In the same grave I further found a well-preserved sandal of almost the same type as those used now in the Puna; small leather bags, containing red, yellow, and green pigments; implements of copper; a thin sheet of copper; an interesting implement of copper (pl. VIII, fig. 3), and a whetstone.

Adjacent to those objects, which are of pure Indian origin, I also found a wind instrument made of cow horn, and the remains of a small knife of iron with a wooden handle. These two articles prove that the ruined city at Casabindo was still inhabited at the period of the Conquista.

At Cangrejillos, in the most northerly part of the Puna, I came upon a dwelling place of considerable size with numerous remains of stone huts. Here was found, among other things, a stone ax of exactly the same type as the Casabindo axes. At Chañi, too, in South Puna, I came upon remains of large-sized villages, one of them at a height of nearly 5,000 meters above the sea. At the topmost summit of the same mountain, at 6,100 meters elevation above the sea, my com-

panions, Herr Von Hofsten and Doctor Fries, found remains of two carefully constructed $\sqcup$-shaped cromlechs, partially covered over with snow. Within the compass of one of the cromlechs there were found a cylindrical bead of blue mineral as hard as glass, and some splinters of pottery of the same appearance as those common in the dwelling places in the Puna. Pieces of cactus wood were also found. It is uncertain whether there was a signaling station here or a place of sacrifice. Owing to the rarefaction of the air, my two peons were unable to proceed to the top. I pushed on alone to the top of one of the peaks, where I took photographs at a height above the sea of about 6,000 meters. Plate v, figures 1 and 2, represent species of sacrificial erections in use among the Puna Indians at the present day; the first is dedicated to the goddess Pachamama, and is formed of stone which are thrown up by every passer-by; the other is in the form of a kind of miniature house, in which chewed cocoa is offered up.

In Quebrada del Toro I visited at Ojo de Agua a dwelling place of very considerable extent. The slope forming the eastern wall of the valley was dotted over with the foundation walls of huts of a rectangular shape; on the western slope, on the other hand, there were none. In digging up a mound on the western side I found numerous graves; consequently that side had been reserved for the dead.

The grave mound is about 13 meters high and 36 meters in diameter. The graves may have been originally marked above the surface of the earth by circles of small stones. I found traces of them at the top of the mound. The mound had evidently, in the process of time, sunk considerably; I could judge that that was so by the skeletons and objects buried there being found in all sorts of positions. Professor Retzius informs me that the heads from this locality, too, are deformed. Many objects were here found in the graves. It is worthy of remark that in almost every grave rattles, consisting of the fruit of the *Juglans australis*, were met with. A specimen of the same description was also found, as I have above pointed out, in the grave of a child at Casabindo. Clay vessels of different types were very common. In addition to a number of other objects resembling those found in the graves at Casabindo I also came upon some implements here which deserve a special mention, as a sort of wooden knives of different sizes, the greater ones (pl. ix, figs. 1, 2) used possibly as knives in battle. The wood in them is particularly heavy and hard, and was undoubtedly brought from Chaco. Some comblike instruments of wood, one of which is shown in plate ix, figure 4, were often found. As to the use they were put to, however, I do not venture even upon a guess. Plate ix, figure 5, shows a copper implement with wooden handle. Implements of that kind, but lacking

FIG. 1.—BARROW IN MOUNTAIN PASS, PUNA DE JUJUY.

FIG. 2.—SMALL STONE ALTARS WHERE COCA IS SACRIFICED BY PUNA INDIANS.

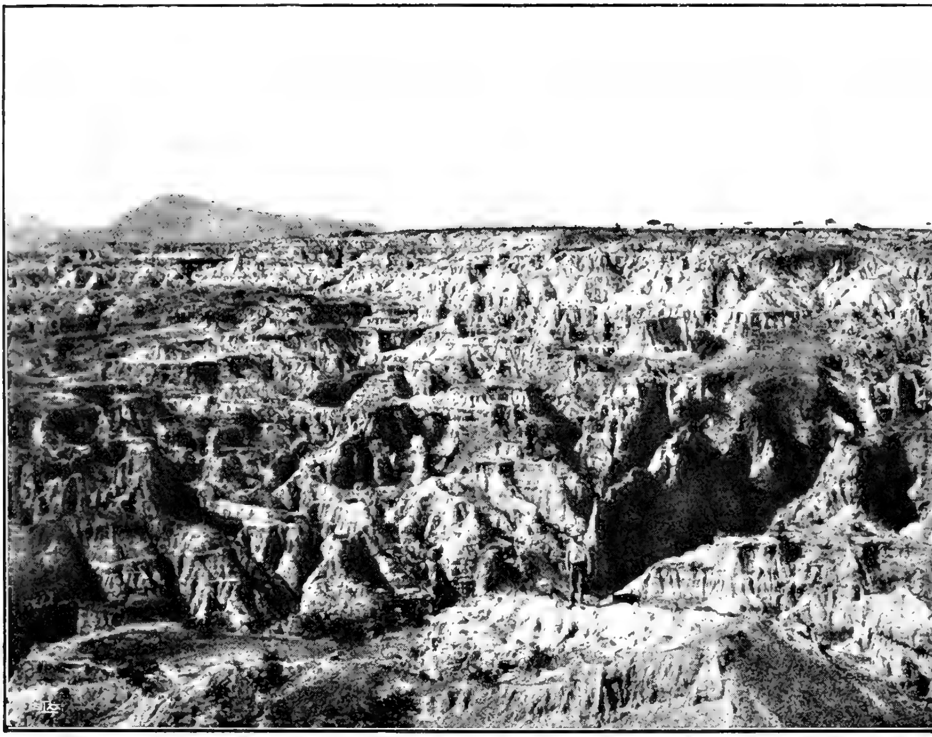


FIG. 1.—LOESS FORMATION IN THE TARIJA VALLEY.

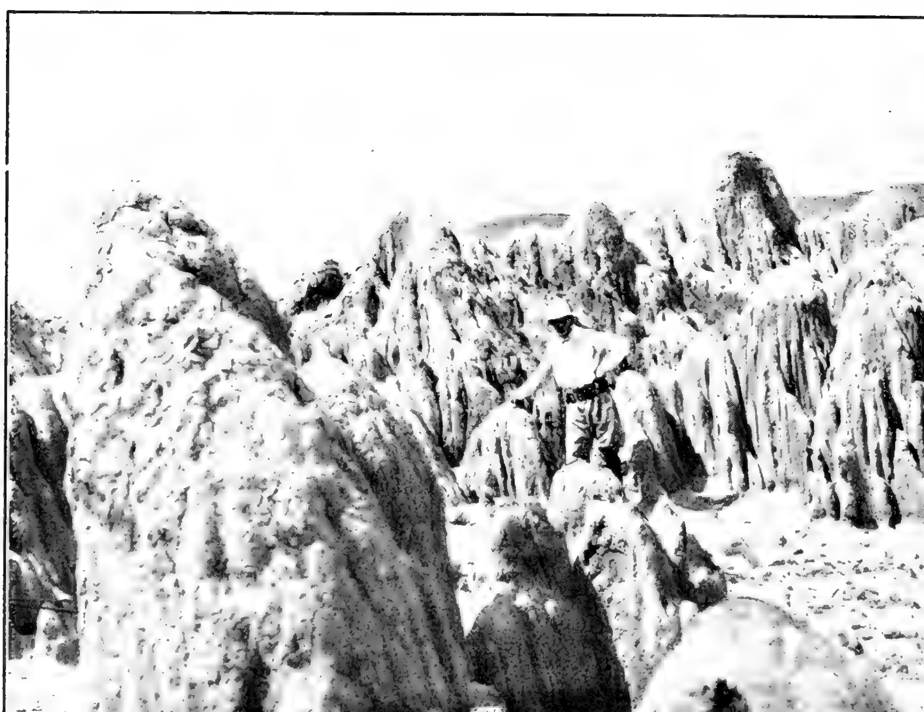


FIG. 2.—LOESS FORMATION IN THE TARIJA VALLEY.

wooden handles, are common enough among the finds in graves in the Puna and neighboring districts. This is the first time they have ever been discovered with their wooden handles still attached to them. There is nothing to show that the handle was bound on with thread or was incased in leather; hence one must assume that the copper implement retained its place in the handle by reason of the pressure of the hand holding it. It is my opinion that these implements were used in cutting out leather.

Before drawing this account to a close, I desire to make mention of a dwelling place that I came upon at Tolomosa, quite close to Tarija, in Bolivia. This dwelling place was far larger, both in extent and in wealth of relics of the past, than any of those I have previously described, and derives, moreover, a special interest from the fact that nothing as regards the archeology of that neighborhood was known before. Owing to the loose nature of the soil, however, and to the tropical rains, all the remains of foundation walls, etc., had been destroyed. The picture of plate VI and on plate VII, figure 1, show how the ground, by reason of its loose consistency, has been scored and furrowed by the rain, so as to produce the most marvelous shapes and figures in its surface. The ground, however, there was dotted almost all over, for an area of upward of a square kilometer, with splinters of pottery, arrowheads, spindle whorls, ornaments, copper implements, etc., while here and there the rain had partially uncovered urns, which it was then possible to dig out of the soil that still encompassed them. To give an idea of the abundance of relics with which the ground around this dwelling place was strewn, I may mention that, among other things, I found upward of 3,000 artistically beaten arrowheads (pl. X, figs. 1 to 5, 7 to 9, 12, 15, and 17) of almost every type, made of flint, obsidian, chalcedony, and rock crystal, and upward of 500 spindle whorls of stone of 24 distinct main types (pl. X, figs. 14, 16, and 18). Further urns of the type which is characteristic of this locality (pl. VIII, fig. 1). An urn of an approximately similar appearance is figured in Doctor Lehmann-Nitsche's catalogue of the finds in the Puna.[a]

Some other clay vessels of different types were also found. One who is figured on plate VIII, figure 2, is of a shape that is very common in Peru. Among other finds, I may mention mortars of stone, a grinding stone with two handles, stone rings, in some cases evidently used as club heads. Further, some pendants in the shape of animal figures (see pl. X, figs. 11, 13), a rattlesnake carved in bone (pl. X, fig. 6), and phallus-like pendants of stone (pl. X, fig. 10) and burnt clay. A few specimens of copper ware—such as rings

[a] Lehmann-Nitsche. Catálogo de las Antigüedades de la Provincia de Jujuy. La Plata 1903. Lám. IV, G, 6.

for the arms and for the fingers, pins with heads shaped to resemble the Llama's, pierced metal disks, implements of the same type as those common in the Puna, and fragments of tweezers—were also found. Some of the copper specimens I have had analyzed, with the result that the material of which they are made is pronounced to be of sterling quality, with but trifling traces of any impurities. The finds from Tolomosa, as well as the other collections I made during the progress of the expedition, are undergoing examination, and I trust I may be able to complete my work upon them in the near future. The collections are all at the ethnological section of the Riksmuseum in Stockholm.

To judge by the finds from the various dwelling places, it would seem as though Ojo de Agua and Casabindo were inhabited by the same tribe, or at all events by tribes nearly related to each other, while in the Tarija Valley, on the other hand, there would appear to have dwelt a population considerably dissimilar to those in the above-enumerated localities. The majority of the specimens found in the graves at Ojo de Agua have counterparts among the finds from Casabindo, e. g., llama bits, bows, implements and ornaments of copper, etc. Common to both localities was the custom of depositing walnut rattles in the graves. These rattles, whose place of origin must have been far-distant wooded regions, were possibly obtained by way of barter with some tribe of the Chaco Indians, or were cherished as relics in commemoration of warlike raids into far-off territories. The find of marine mussels proves that the inhabitants of the Puna must have come into contact with tribes who lived far removed from them. The custom of burying children in clay vessels was prevalent both at Ojo de Agua and at Casabindo, and all the heads from those two localities display deformation both as regards adults and children. The only head, on the other hand, which I succeeded in discovering in the Tarija Valley does not show any trace of having been deformed. The specimens discovered at the last-mentioned locality are, moreover, with few exceptions, of an entirely different type from the Puna ones. The few isolated articles that are similar to specimens from Ojo de Agua and Casabindo, have, in all probability, come into the hands of the inhabitants of the Tarija Valley through the channel of trade with the people of the Puna. Further, at several dwelling places in the Puna, among others at Cangrejillos, I discovered here and there an isolated specimen of arrowheads analogous to those which are characteristic, both in type and variety of flint, of the Tarija Valley. As regards the age of the different dwelling places, the finding of the iron knife and the cow horn at Casabindo proves, of course, that the ancient culture, at any rate at that locality, continued on till the invasion of the Spaniards; but at all the other dwel-

ling places I investigated, both in the Puna and at Tolomosa, no object was met with that could suggest foreign influence, and that, although the number of specimens obtained from the last-named locality was several thousands, it is still a tolerably risky proceeding to endeavor to identify the former inhabitants of the dwelling places with any still extant Indian tribe. More extensive research is requisite before that can be attempted with any certainty of correctness. Many circumstances point, nevertheless, to the Indians now living in the Puna, though their numbers are exceedingly small, as descendants of the tribes that were once so numerous and so powerful in these regions. In spite of the great uncertainty still attaching to this problem, I have, nevertheless, thought it desirable to touch upon it here, in order to give rise possibly to a discussion upon it.

FIG. 1.—LOESS FORMATION IN THE TARIJA VALLEY. IN FOREGROUND FOSSIL BONES OF THE MASTODON ANDIUM, WASHED OUT BY RAIN.

FIG. 2.—MODERN IND'AN HUT IN THE TARIJA VALLEY.

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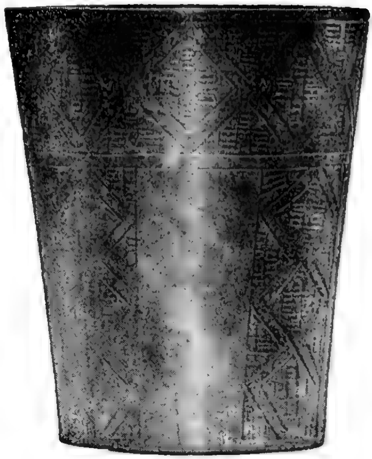
Fig. 1. Painted Clay Vessel, Tarija. Height, 17 Cm.—Fig. 2. Red Clay Vessel, Tarija. Height, 20.7 Cm.—Fig. 3. Copper Implement, Casabindo. Breadth, 6.9 Cm.—Fig. 4. Mutilated Stone Adz, Casabindo. Length, 11 Cm.



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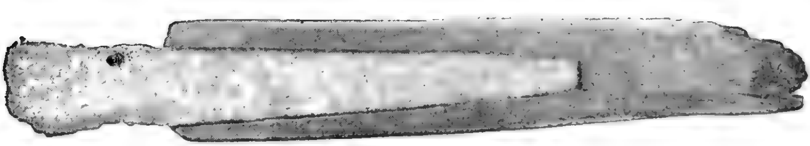

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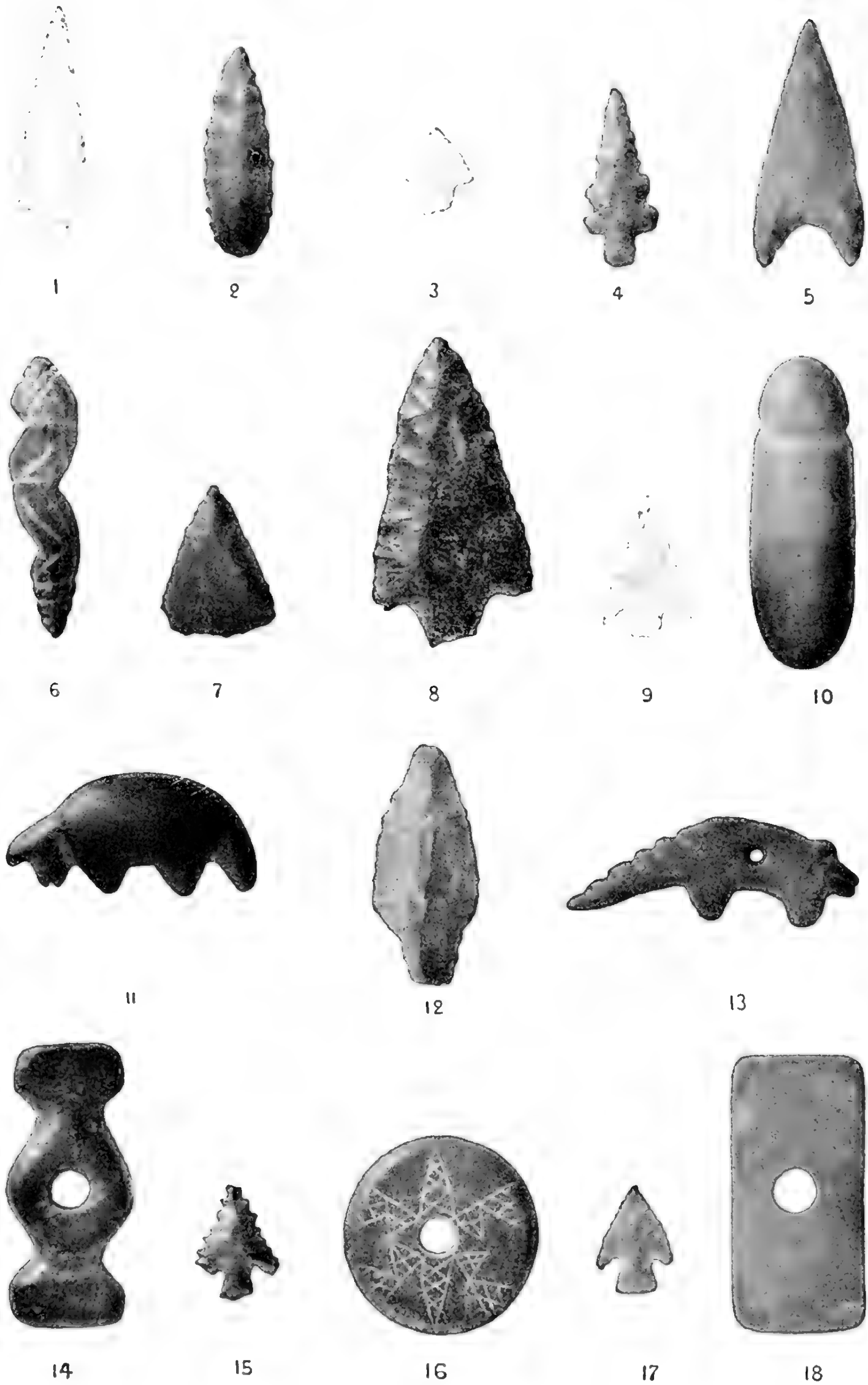
FIG. 1. WOODEN IMPLEMENT, OJO DE AGUA. LENGTH, 47 CM.—FIG. 2. WOODEN IMPLEMENT, OJO DE AGUA. LENGTH, 31 CM.—FIG. 3. WOODEN GOBLET, CASABINDO. HEIGHT, 16.1 CM.—FIG. 4. COPPER CHISEL WITH WOODEN HANDLE LENGTH, 14.5 CM.



OBJECTS FOUND AT THE ANCIENT DWELLING PLACE NEAR TOLOMOSA, IN THE TARIJA VALLEY. NATURAL SIZE.

A GENERAL VIEW OF THE ARCHEOLOGY OF THE PUEBLO REGION.

By Edgar L. Hewett.

I. Limits of the Region.

The term "pueblo region" has not yet been acceptably defined. As used in this paper it designates that portion of the United States over which are distributed the archeological remains and the living remnants of those aboriginal North American tribes which from their chief common characteristic, that of permanent substantial house building, received from the Spanish conquerors the name of Pueblo or town Indians. It embraces almost the whole of New Mexico and Arizona, with small portions of southwestern Colorado and southeastern Utah. There is probably no reason why the term should not be extended to embrace large portions of the states of Sonora and Chihuahua, in Old Mexico.

To determine the exact limits of the pueblo region is one of the tasks of American archeology that awaits completion. Special exploration with a view to the determination of these limits has not yet been undertaken. However, the archeological remains are of so conspicuous a character that the boundaries are approximately revealed. I accept the Pecos valley, in eastern New Mexico, with its tributary the Gallinas, as the eastern limit. Straggling ruins are found farther east, in Scott County, Kans., and in the Canadian valley, in Texas; but these are remains of temporary settlements. There is no well-established evidence of serious attempts by the aborigines to form permanent substantial settlements upon the "great plains." Those easterly remains of pueblo culture in the Gallinas valley near where the city of Las Vegas now stands and in the Pecos valley in the vicinity of the present Anton Chico were also comparatively transitory. The northern limit is less definite, but is approximately the northern rim of the San Juan Basin, in Colorado and Utah. Such pueblo settlements as were formed north of the San Juan-Grand divide—for example, those of the Lost Canyon

and others in the Dolores drainage—were of little importance. On the west and northwest the limit is the northwestern outline of the basin of the Rio Colorado. Pueblo settlements beyond this boundary were few. On the east side of the river typical pueblo culture flourished. Passing to the western side we find it gradually ceased to be characteristically pueblo. On the south the boundary as accepted in this paper is the southern rim of the Gila valley. This limitation is purely arbitrary, however, as traces of identical or but slightly differing culture extend much farther south.

An examination of the physiography of the frontiers of this culture is instructive. East of the Pecos and of the Rocky mountains are the vast unbroken grassy plains, the great cattle range of recent years, and the favorite buffalo range of earlier times. The buffalo afforded the principal food supply for the plains Indians. It was an unstable source of subsistence. This, in primitive life, induces a correspondingly mobile population, whereas a culture of the Pueblo type is based on sedentary habits. Physiographic conditions account for the arrest of Pueblo culture east of the Pecos. Its failure to extend west of the Colorado is likewise a matter of physiography, for along the lower course of this river absolute aridity prevented settlement, while farther up the great chasm of the Grand Canyon barred migration. The reason for the arrest of the Pueblo frontier on the north with the San Juan-Grand watershed is not so apparent. To the northeast was an excellent game country, full of warlike hunting tribes, forming an effective barrier in that direction, but to the northwest through Utah and Nevada the physiographic conditions were altogether favorable to the Pueblo culture, and an open gateway in that direction is found east of the Colorado. On the south the Gila does not constitute either a physiographic or ethnographic boundary, since similar conditions extend down into Mexico. By common usage the name "Pueblo" is applied only to tribes within the United States, disregarding the ethnic similarities of north Mexican tribes. Here we find natural gateways for the entrance of early immigrants into Pueblo territory from the Rio Grande at the southeast and along the Gila and its tributaries from the southwest.

There is thus inclosed within the boundaries above described a physiographic area which is accurately characterized by the term "semiarid," the limits of which are approximately coextensive with the limits of the Pueblo culture. The climatic conditions are peculiarly definite. Dryness is the prevailing condition. Precipitation is very unequally distributed throughout the year. Heavy rainfalls of from a few hours to some days' duration are followed by months devoid of moisture. The character of the soil is such that the effects of rainfall rapidly disappear. Absorption, evaporation, and drain-

age proceed with great rapidity. Between the Pecos and the Colorado are extensive plateaus of inferior grass lands, timbered mountain ranges, narrow arable valleys, and vast stretches of sandy desert. Much of the area exceeds a mile above sea level. The country was probably always deficient in game, neither were wild fruits plentiful, nor was any indigenous food supply abundant.

These physiographic conditions exercised a coercive influence over the primitive culture of the Southwest, making fixed abodes and an agricultural basis of food supply necessary. To the east and north nomadic hunting tribes followed where the food quest led them. They shunned the southwestern desert for the same reason that the buffalo did. Navahoes, Comanches, and Apaches did not invade this region until comparatively recent years, for obvious reasons. In the economic systems of primitive men we find the germs of up-to-date commercialism. Wealth is obtained by producing it and by dispossessing others of it. The tribes mentioned belonged to the predatory class. As game was scarce in the Southwest, there was no reason for their going there until it became worth while for predatory reasons.

The true indigines of the Southwest were necessarily agriculturists. Coming into a region where game and wild fruits afforded insufficient subsistence, they, probably partly from previous experience and partly from immediate necessity, were constrained to supplement their food supply by the cultivation of food plants. The preparation of ground for agriculture and the necessary devices for the utilization of water for irrigation induced a comparatively permanent abode and substantial house building. Settlements, with rare exceptions, were perforce clustered in narrow valleys along waterways, or in cliffs, or on mesa tops, within reach of streams or perennial springs.

Thus the indigines of the Southwest were and are Pueblos (town builders) through the coercion of physiographic environment. As an ethnic division they are a most indefinite one, embracing several well-established linguistic stocks and numerous minor dialectic groups, which become more numerous the farther back they are traced. Every existing Pueblo tribe that has been studied has been found to be composite, formed by combination of sundry ethnic groups more or less amalgamated. Incoming bands, regardless of blood or previous condition, if they came seeking permanent abode, became Pueblos, whether they amalgamated closely by blood with previous settlers or not, by virtue of their enforced adoption of the mode of life made necessary by the physiographic conditions of the region. Similarity of house life, of food, of method of acquiring the same, of inventions necessary to food production, of utensils for conserving and transporting the scant and precious water supply, of

experience with the elements and soil, of suffering from famine and foes, in time led to a degree of like-mindedness which found corresponding expression in religious belief, in esthetic feeling, in social organization. The Pueblo tribes, while remaining unlike as to language and somatic characteristics, naturally became alike in general and specific culture. Some of these elements of likeness may be stated as follows: They were all producing rather than predatory tribes; they preferred sedentary to nomadic life; they preferred stable rather than transitory homes; they developed a societary system founded on "mother right;" they evolved a highly complex theogony, characterized by elaborate rain and growth ceremonials; they developed highly the art of pottery with elaborate symbolic ornamentation.

The name "Pueblo" is thus almost without ethnological significance, having no reference to tribal or linguistic relationship, but relating mainly to a type of culture that developed in response to the influence of a definite physiographic environment, the limits of which were fixed by nature as above set forth.

II. Classes of Archeological Remains.

A much greater variety of archeological remains exists in the Southwest than in other parts of the United States, owing to the permanence of abodes, the adaptation of climate to the preservation of artifacts usually perishable, and the comparatively uninhabited condition. While in other parts of the country little save the contents of graves, consisting of stone implements, pottery, and osseous remains, now exist, and the majority of these lost or disturbed by the progress of agriculture, here we find not only graves and all the usual mortuary remains, but extensive remains of houses in every stage of preservation, with all the appurtenances of domestic life preserved therein, and numerous shrines, ceremonial deposits, and an extensive paleography displaying the esthetic and religious life.

The ruins of domiciliary structures are capable of division, not on structural differences, but by situation, into the two general classes—pueblos and cliff dwellings. The first embraces all those multiple-chambered structures, either single or in clusters, that are situated on mesas or in valleys independent of support from natural rock walls. The second includes those that are wholly or in part embraced within cliffs, built against cliffs, or situated on ledges under overhanging cliffs, either single or multiple chambered. The location of the village of a pre-Columbian sedentary tribe was selected primarily with reference to water and arable lands. This was modified in time by the necessities of defense against incoming predatory enemies, which multiplied as the Pueblos accumulated food supplies sufficient to make them desirable prey. The kind of a house to be built was

FIG. 1.—RUINS OF PUYE PUEBLO, PAJARITO PARK, NEW MEXICO.

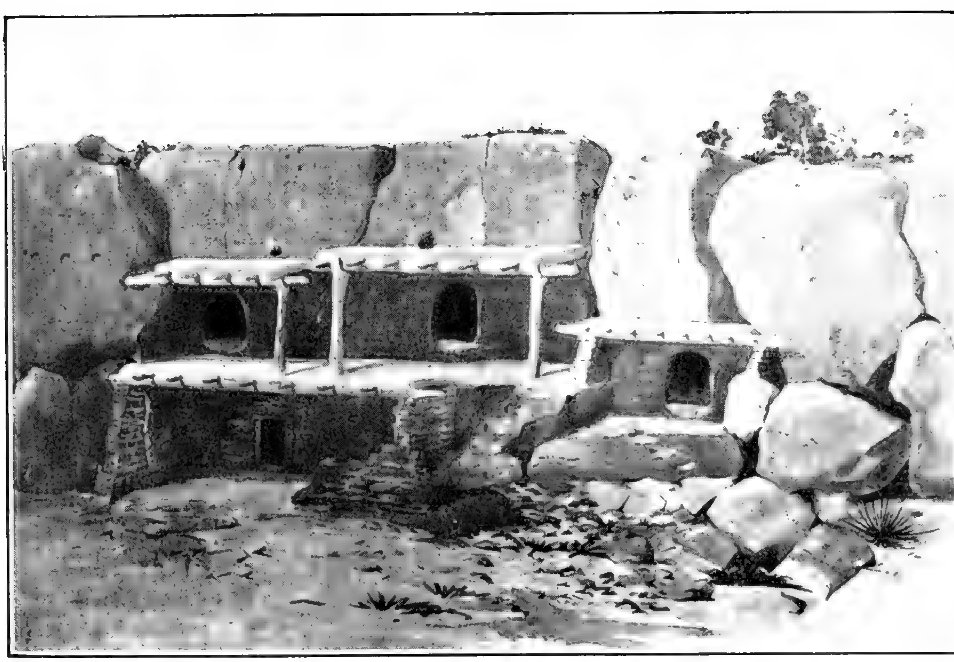
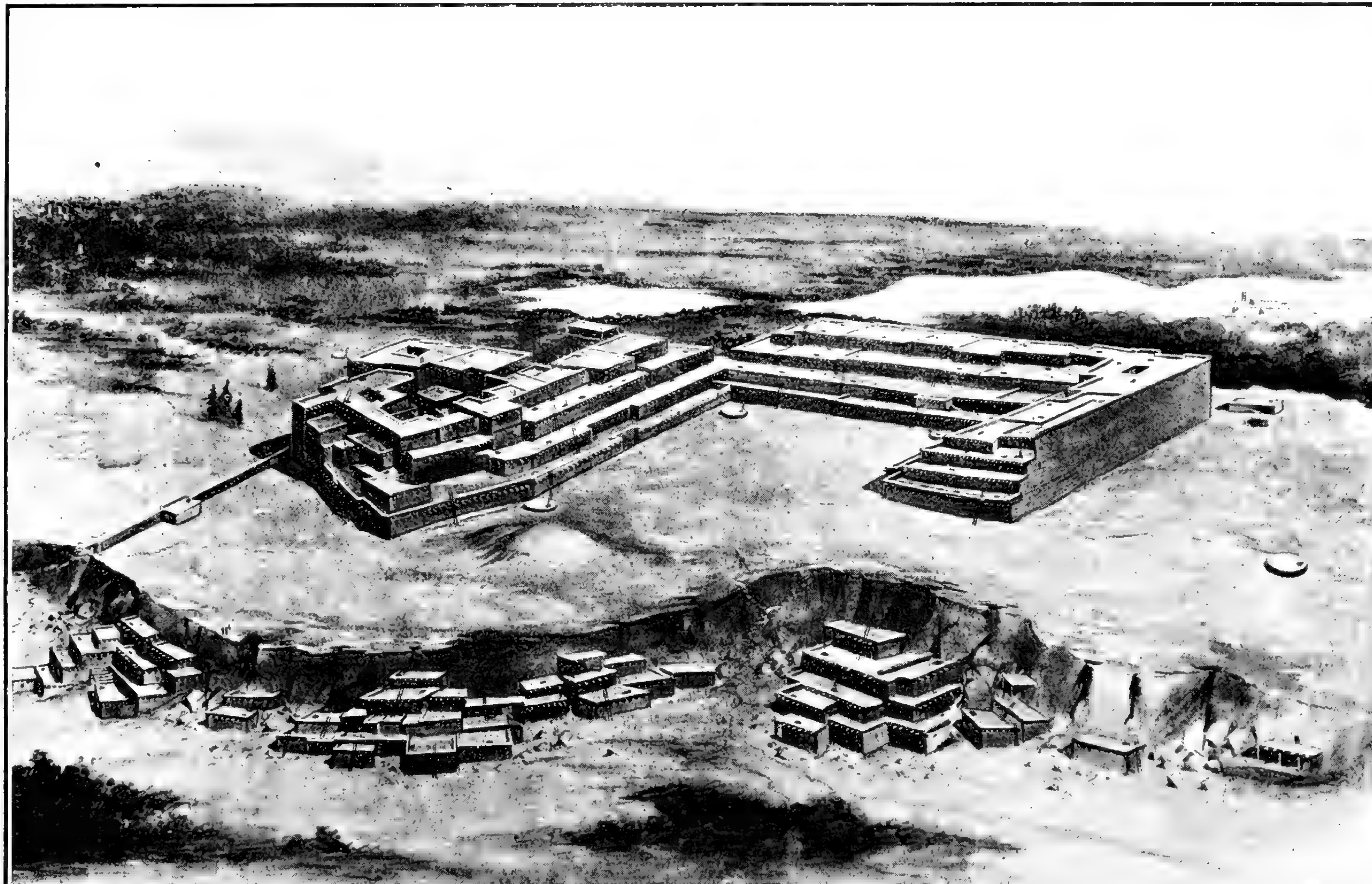


FIG. 2.—CLIFF DWELLINGS IN SANDIA CANYON, PAJARITO PARK, NEW MEXICO (RESTORED).

Restoration by Kenneth M. Chapman.



PUEBLO OF TCHIREGE, PAJARITO PARK, NEW MEXICO (RESTORED).

Restoration by Kenneth M. Chapman.

determined by the geology of the location. If in the open, sandstone or tufa blocks, bowlders, and adobe were used, as furnished by the environment, and the structure timbered with what nature supplied. If considerations of defense necessitated a cliff dwelling, its character was a geological question. Great natural caves and recesses under overhanging cliffs were selected, and houses not structurally different from the pueblos in the open were built within them. Such formations occur numerously throughout the Rio Colorado drainage area. Accordingly we find this class of cliff dwellings distributed over the valleys of the San Juan, Little Colorado, Gila, and their tributaries.

In cliffs of volcanic tufa, or other material sufficiently friable to permit of easy working with stone tools, dwellings were excavated. Small natural caves in such regions were utilized as dwellings, with or without further excavation, and both with and without masonry. Large open caves were sometimes walled up. Interior walls were sometimes built. Houses not structurally unlike pueblos in the open were built in front of these excavated rooms against the cliffs. The name "cavate dwelling" (originally proposed by Professor Mason) has long been applied to excavated cliff dwellings. They are distributed over the four drainage basins of the pueblo region, being most numerous on the western tributaries of the Rio Grande, the northern tributaries of the San Juan, and the northern tributaries of the Gila, particularly the Rio Verde.

III. Distribution.

The distribution of the Pueblo culture, as disclosed by archeological remains, was determined primarily by drainage. The region lies on both sides of the Continental divide. The eastern portion is drained by the Rio Grande and its tributaries; the western by three principal tributaries of the Rio Colorado, viz, the San Juan, the Little Colorado, and the Gila. These four drainage basins constitute the primary seats of Pueblo culture.

The primal needs of primitive man are water, food, and shelter. In the Southwest, water was first in importance. Where water was, food was possible. Such game as the country supported frequented waterways and springs, and here only were to be found the conditions necessary to the production of food plants. Accordingly, the extension of the indigenous culture was directed by the drainage, and so thoroughly did it overspread the region under consideration that there is not a valley of any consequence from the Pecos to the Colorado, and from the San Juan to the Gila, that is without its characteristic archeological remains. Following is a list of the principal valleys, basins, canyons, and mesas containing ruins:

1. Rio Grande Drainage.

Main valley from El Paso to Embudo Canyon.

Eastern tributaries:
- The upper Pecos.
- The Gallinas.
- The Tunque.
- The Galisteo.
- The Pojoaque.
- The Nambe.
- The basin of the Manzano salt lakes.
- The Tajique.
- The San Pedro.
- The Santa Fe.
- The Tesuque.
- The Santa Cruz.

Western tributaries:
- The Chama.
- The Santa Clara.

Western tributaries—Continued.
- The Alamo.
- The Pajarito.
- The Rito de los Frijoles.
- Cañada de Cochiti.
- The Puerco.
- The Cebollita.
- Montezuma Mesa.
- The Ojo Caliente.
- The Chupadero.
- The Sandia.
- The Bravo.
- Cañada de la Cuesta Colorada.
- The Jemez.
- The San Jose.
- The Alamosa.
- The Mimbres (inland).

Numerous dry creeks of the Acoma Plateau and Magdalena district.

2. San Juan Drainage.

Main valley from source to junction with Pine Creek.

Southern tributaries:
- In New Mexico—
  - Canyon Largo.
  - Compañero Canyon.
  - Gobernador Canyon.
  - Chaco Canyon.
- In Arizona—
  - The Chinlee.
  - The Hospitito.
  - Canyon del Muerto.
  - Gothic Wash.
  - Marsh Pass.
  - Canyon de Chelly.
  - The Carrizo.
  - Monument Canyon.
  - The Nashlini.
  - Paiute Canyon.

Northern tributaries:
- In Colorado—
  - Las Animas.

Northern tributaries—Continued.
- In Colorado—Continued.
  - The Mancos.
  - Moccasin Canyon.
  - Ute Canyon.
  - Johnson Canyon.
  - The Yellowjacket.
  - La Plata.
  - The Mesa Verde.
  - Navaho Canyon.
  - Ruin Canyon.
  - The McElmo.
- In Utah—
  - The Hovenweep.
  - The Recapture.
  - Butler Wash.
  - Grand Gulch.
  - The Montezuma.
  - The Cottonwood.
  - Comb Wash.

3. Little Colorado Drainage.

Main valley, entire course.

Northern tributaries:
- The Moencopie.
- Corn Creek.
- The Puerco.
- The Carrizo.
- The Hopi Plateau.
- Le Roux Wash.
- Cottonwood Wash.

Northern tributaries—Continued.
- The Zuñi.

Southern tributaries:
- Silver Creek.
- Walnut Canyon.
- The Chevlon.
- Chavez Pass.

4. Gila Drainage.

Main valley from source to below Phenix.

Northern tributaries:

- The Verde.
- Oak Creek.
- Clear Creek.
- The East Verde.
- The Tonto.
- Canyon Creek.
- The Carrizo.
- The Bonito.
- The San Carlos.
- The San Francisco.
- The Tularosa.
- The Cottonwood.

Northern tributaries—Continued.

- Beaver Creek.
- Pine Creek.
- The Salt.
- Cherry Creek.
- The Cibicu.
- White Mountain Creek.
- The Pinal.
- Eagle Creek.
- The Blue.

Southern tributary:

- The San Pedro.

IV. Preservation.

Present state.—The present state of preservation of the southwestern ruins depends upon several conditions. Cliff dwellings, because of their sheltered situation, are much better preserved than pueblos in the open. Of the former class those of the excavated type are naturally the best preserved, since in many of them there are no artificial walls at all and deterioration occurs only with the falling away of the natural rock. This form of deterioration does occur to a destructive extent in many places and manifestly is not preventable, but even in the absence of all protective measures thousands of specimens of this class of domiciles would remain in a state of perfect preservation for ages. The pueblo-like cliff dwellings being situated under heavy overhanging ledges are well protected from the elements and unmolested would endure for centuries. But their destruction seems to have been made the peculiar pastime of a certain class of human beings. The early explorers of the Mancos Canyon would now find, in many cases, unrecognizable heaps of stone where thirty years ago were well-preserved structures. The excavation of cliff dwellings without due regard to the preservation of walls should be made a grave misdemeanor. The preservation of these remains is now almost entirely a matter of protection from vandals, since they are quite perfectly sheltered from the elements.

The ruins of pueblos are exposed not only to vandalism but also to the constant destructive effects of the weather. In most cases the buildings are almost totally destroyed, only small fragments of walls remaining standing above the débris. Noted exceptions to this are illustrated in accompanying plates. The height of walls bears little relation to the age of ruins. The difference in the state of preservation is due principally to the character of the material used in construction and the degree of exposure to vandalism. In some cases walls have been taken down by the settlers and the stones used in the

construction of buildings, corrals, etc. Much destruction was wrought in earlier times by the removal of the timbers for firewood by settlers and passing campers, thus causing the collapse of all walls above the first story. Ruins in the treeless desert have suffered especially from this cause. The material used in building has much to do with the state of preservation. Other things being equal, the pueblos that were built of small bowlders and adobe were the first to succumb to the elements and are most reduced, the convex surfaces of the stones affording little stability to the walls as the plastering and chinking material weathered out. The Rio Grande pueblos were mostly of this class and are reduced to mounds. Somewhat more durable were those built of tufa blocks as in the Pajarito Park pueblos. But here also the imperfectly flattened surfaces of the stones are readily freed by the weather from the supporting mortar and chinking stones, and collapse of the walls readily occurs. The best preserved of all are those built of laminated sandstone as in Chaco Canyon. The flat slabs fit together perfectly with but little mortar or chinking to weather out, so that the walls, even in the absence of timbers, remain intact until thrown down by human agency.

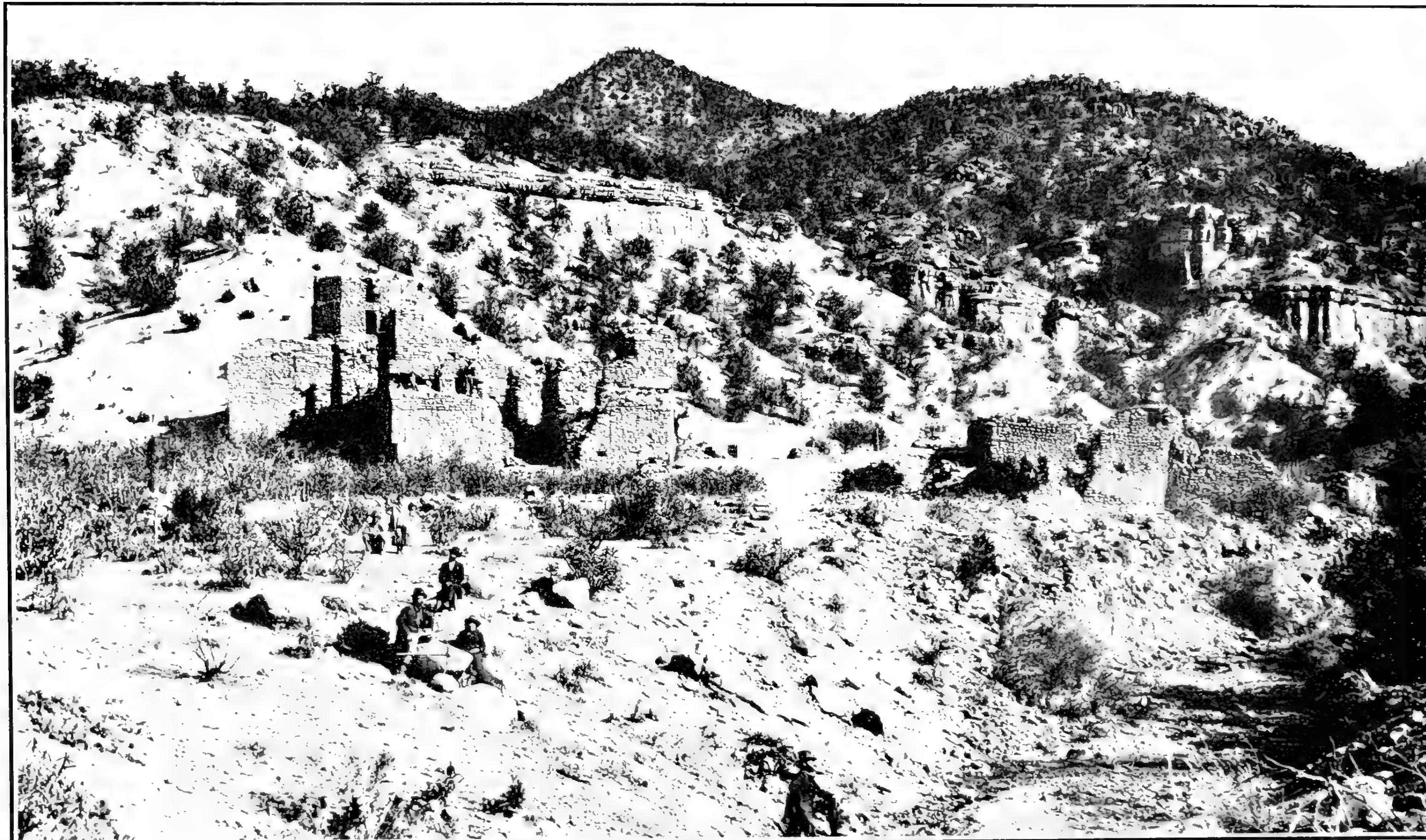
Future preservation.—The subject of preservation of American antiquities is now receiving an amount of attention never heretofore accorded it. For a quarter of a century certain thoughtful people have been calling attention to the matter and the continuous publication of archeological and ethnological literature is bearing fruit. Learned societies, scientific and educational institutions, legislative bodies, and public-spirited individuals are beginning to devote to the question consideration commensurate with its importance. The problem is an intricate one. A more general diffusion of information concerning it is urgently needed.

Of the archeological remains in the Southwest, probably nine-tenths are on lands yet owned or controlled by the Government of the United States, mainly upon forest reserves, Indian reservations, lands withdrawn from entry for special purposes, military reservations, and unappropriated public lands. So the question may still be dealt with through the National Congress and Executive Departments. In some cases it may become necessary to interest States and Territories in preservative measures, and in others private owners, railroad companies, and companies owning land grants will need to be impressed with the importance of preserving these remains for archeological research.

Preservation must be:

(1) Permanent in cases where the condition and historic or ethnic significance of the ruins give them special educational value.

(2) Temporary in the case of all aboriginal buildings, graves, and other archeological remains not included in the first class, the pro-



RUINS OF PUEBLO OF GIUSEWA AND MISSION OF SAN DIEGO, JEMEZ VALLEY, NEW MEXICO.

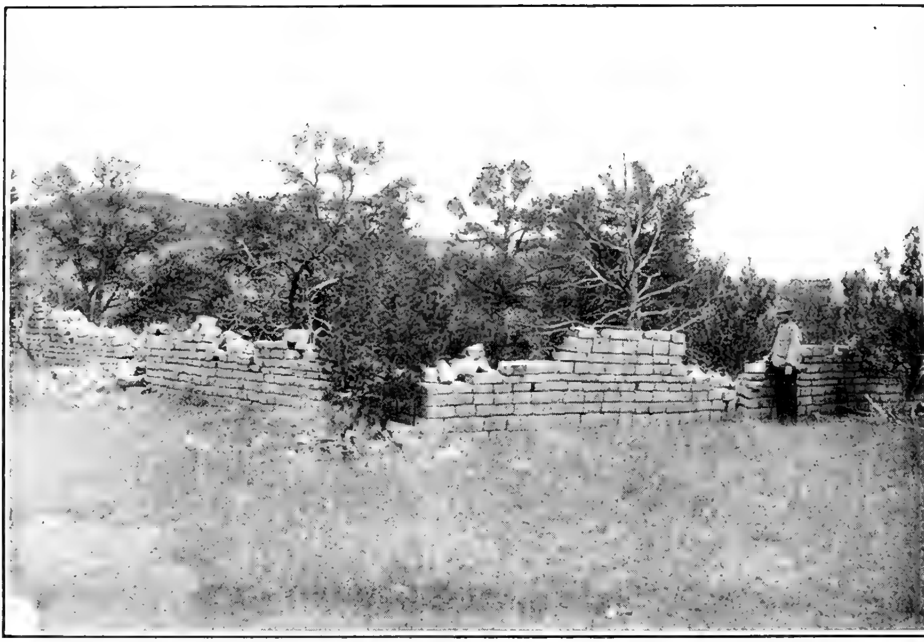


FIG. 1.—PUEBLO RUINS, MONTEZUMA MESA, NEW MEXICO.

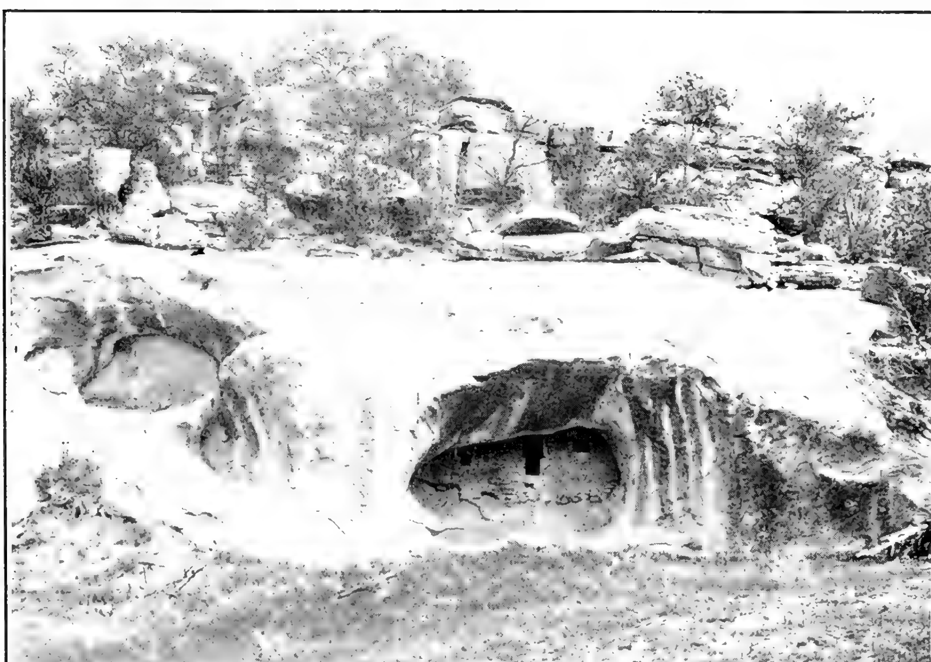


FIG. 2.—CLIFF DWELLING, MONTEZUMA MESA, NEW MEXICO.

tection to be afforded until all data of importance to science have been investigated and all artifacts in connection therewith removed to museums for permanent preservation.

Preservation is to be secured:

(1) Through Congress: Under special legislation creating national archeological reservations or parks and general legislation establishing a system of custodianship and administration over all archeological remains on the lands owned or controlled by the Government of the United States. Up to date but one measure looking toward the preservation of antiquities has ever been passed by the National Congress, and this provided for the preservation of a single building—Casa Grande, in Arizona. As early as 1896 a general bill was prepared and presented to the National Congress and similar measures have been introduced since from time to time down to the 58th Congress, but none have passed.

(2) Through Executive Departments: By the exercise of powers inherent in such departments under the Constitution and General Statutes. With the single exception above noted, all that has been accomplished by way of protection of antiquities has been by this method. It is exceedingly fortunate that, as will be seen further on, so much can be provided for incidentally in connection with the administration of our great economic, Indian, and military interests, thus involving but little additional expense.

By virtue of section 441, United States Revised Statutes, the care and custody of the public lands is vested in the Secretary of the Interior, and section 453 declares that the Commissioner of the General Land Office shall perform, under the direction of the Secretary of the Interior, all executive duties in any wise respecting such lands. There can be no question that this statute places upon the Department of the Interior and the General Land Office the obligation to protect the archeological remains that are upon the public lands as definitely as it does any other values thereon.

In the exercise of the power thus conferred a policy has developed in the General Land Office and Office of Indian Affairs, under the Department of the Interior, that is highly commendable as far as it goes. This policy utilizes forest supervisors and rangers, special agents, Indian school superintendents, Indian agents, additional farmers, and police in the protection of ruins in connection with and as one of their regular duties for the avowed purpose of preserving them for scientific investigation. It establishes the liberal policy that any competent scientist who desires to place the material secured in a public museum will be authorized by the Department of the Interior to examine ruins, but that no person will be permitted to excavate them for the purpose of acquiring specimens for traffic or private gain, and that willful destruction of historic and prehis-

toric landmarks must cease. Especially noteworthy is the emphasis laid by the Commissioner of the General Land Office on "the importance of furthering in every way possible researches with a view to increasing the knowledge of such objects and aiding the general advancement of archeological science." Every thinking man will uphold this policy most cordially.

As above stated, practically all that has been accomplished thus far has been through the exercise of powers inherent in the executive branches of the Department of the Interior. This authority is readily invoked, and in the past has responded with great promptness to every reasonable recommendation. By this means the following protective measures have been secured:

1. Through the General Land Office:

(*a*) All ruins on forest reserves[a] have been placed under the care of the regular forest rangers. This includes the vast number of ruins on the Gila Forest Reserve, the Black Mesa Forest Reserve, the San Francisco Mountains Forest Reserve, and a considerable number on the Grand Canyon Forest Reserve.

(*b*) The Pajarito Park, in New Mexico; the Mesa Verde Park, in Colorado, districts containing vast numbers of prehistoric ruins, and a tract on which stands El Morro or Inscription Rock, in New Mexico, a most important historic landmark, have been withdrawn from disposal under the public-land laws and recommended for permanent preservation as national parks, as has also the petrified forest in Arizona, withdrawn primarily for preservation as a natural wonder, but also containing important ruins.

(*c*) The proposed Jemez and Taos forest reserves, in New Mexico, and the proposed Rio Verde Forest Reserve, in Arizona, have been withdrawn from entry or disposal. This will incidentally preserve a vast number of important ruins.

(*d*) The ruins situated on unappropriated public lands have been held to be subject to the authority of the Department of the Interior and orders have been issued through special agents prohibiting injury and unauthorized excavation.

2. Through the Office of Indian Affairs:

(*a*) Special custodians have been appointed for ruins in Canyons del Muerto and de Chelly on the Navaho Reservation in Arizona; for those on Mesa Verde on the southern Ute Reservation in Colorado, and for those on the Zuñi Reservation in New Mexico.

(*b*) The office prohibits all unauthorized persons from entering Indian reservations and despoiling ruins or carrying away remains of antiquity.

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[a] Jurisdiction over forest reserves transferred to Bureau of Forestry, Department of Agriculture, February 1, 1905.

(*c*) Order of February 11, 1905, prohibits licensed Indian traders from dealing in prehistoric wares, thus removing from the Indians and other persons the temptation to despoil the ancient cemeteries for the sake of the small profits to be derived therefrom. This corrects an abuse that has been very prevalent and disastrous.

Up to the present time there has been no coordination of the efforts of the various departments of government along this line; no general supervision is exercised; no systematic reports on the condition of the ruins are required; no system for regulating excavations and the disposition of specimens exists. The matter should no longer be dealt with sporadically. What is needed is a comprehensive system of administration and regulation for the whole subject.

Measures for the preservation of antiquities can not be intelligently framed without consideration of their situation with reference to ownership or jurisdiction. In this respect all those of the Pueblo region may be classified as in the following list. Below each class I have indicated the executive officer having jurisdiction over the class of lands named and necessarily of all antiquities thereon.

1. Those on national reservations or parks:
   The Secretary of the Interior.
2. Those on forest reserves:
   The head of the Bureau of Forestry, under the Secretary of Agriculture.
3. Those on Indian reservations:
   The Commissioner of Indian Affairs, under the Secretary of the Interior.
4. Those on military reservations:
   The Secretary of War.
5. Those on unappropriated public lands:
   The Commissioner of the General Land Office, under the Secretary of the Interior.
6. Those on lands withdrawn from entry for special purposes:
   The Commissioner of the General Land Office, under the Secretary of the Interior.
7. Those on State lands.
8. Those on private lands (railroad lands, grants, homesteads, etc.).

In the appended list of important districts and sites the jurisdiction if known is indicated.

The first class includes at present only Casa Grande in Arizona, but important additions to this class are contemplated by certain bills that have been before Congress for some years. The protection of ruins in such reservations or parks is always adequately provided for by special service.

The second class, those on forest reserves, includes, as will be seen by reference to the list, a large proportion of the most important ruins. By act of Congress of February 1, 1905, the administration of forest reserves was transferred from the Commissioner of the General Land Office, Department of the Interior, to the forester and

chief of the Bureau of Forestry, Department of Agriculture. Forest reserves are constantly patrolled by a force of forest rangers, and the policy developed in the General Land Office of making it the duty of these officials to protect ruins from despoliation is continued under the Bureau of Forestry. This is all that could be desired. It may be said that ruins of this class are the most fortunately situated of all, for they are no longer liable to alienation by sale or entry of the lands, and are adequately policed, with little or no expense for special service. Large additions will be made to this class when the proposed Jemez, Taos, and Rio Verde forest reserves are established.

The third class, those on Indian reservations, includes a large proportion of the most important sites. The Office of Indian Affairs fully recognizes the obligation to protect the ruins and prevent unauthorized excavation, and is, moreover, furnished with appropriations and clothed with authority to utilize the same for the employment of such additional service as is necessary. Special custodians are employed in districts of unusual importance, and this service will doubtless be extended as need therefor is shown. It may be said that all ruins that come under this class are in a position to be adequately protected.

The fourth class, those on military reservations, are not numerous, and the attention of the War Department has not of late been called to the necessity of protecting them. Undoubtedly this Department would take the necessary steps if advised of the desirability of the same, and it doubtless has facilities for effective custodianship without providing special service therefor.

The fifth class, those on public lands, are quite numerous, but not nearly so numerous as has been supposed. The inadequacy of all general archeological measures that have been proposed heretofore, so far as I have been able to determine, lies fundamentally in the fact that they have not taken cognizance of the legal definition of the term "public lands." The courts have held the term "public lands" to signify the Federal lands lying open on the market for preemption or homestead, and that when the Government has reserved certain holdings from preemption they ceased to be "public lands."[a] Thus limited, class five will probably not include over 15 per cent of all the ruins on lands owned or controlled by the Government of the United States, and on the list of important districts and sites it will be seen that very few fall within this category. These lands, with everything situated thereon, are constantly being alienated by preemption, railroad selections, and lieu selections. Furthermore, with

[a] Oral opinion rendered by Judge Wellborn in civil suits in southern district of California against A. H. and L. A. Blassingame. See also United States *v.* Tygh Valley Land and Live Stock Company (76 Fed. Rep., 693).

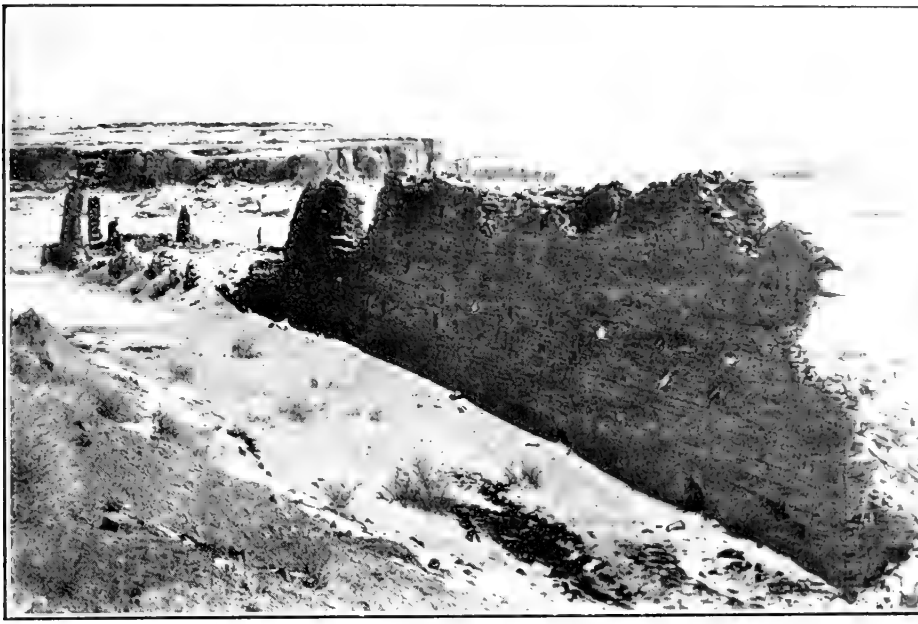

FIG. 1.—RUINS OF HUNGOPAVI, CHACO CANYON, NEW MEXICO.

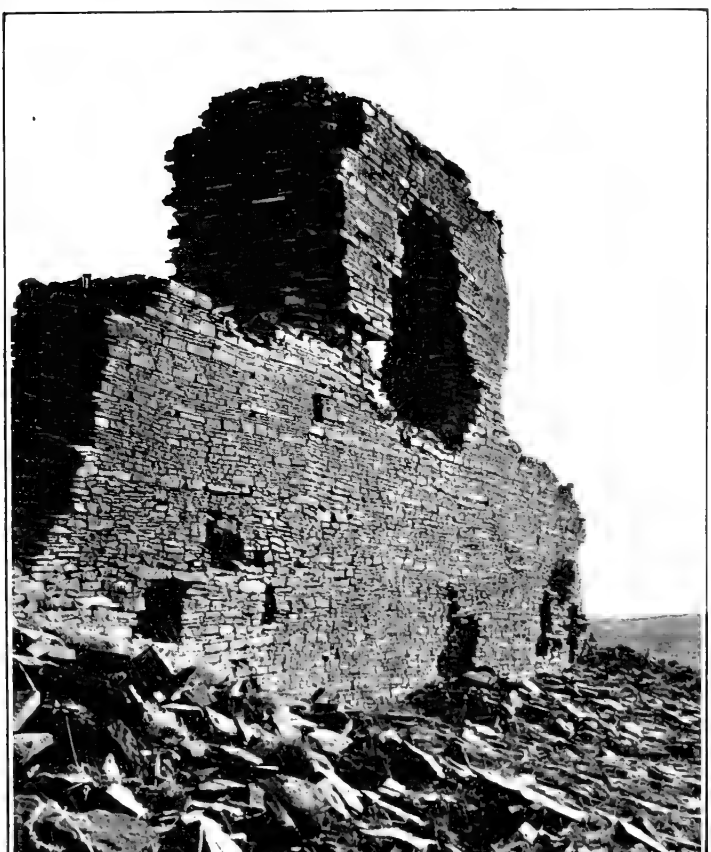

FIG. 2.—RUINS OF KINKLIZHIN, NEAR CHACO CANYON, NEW MEXICO.

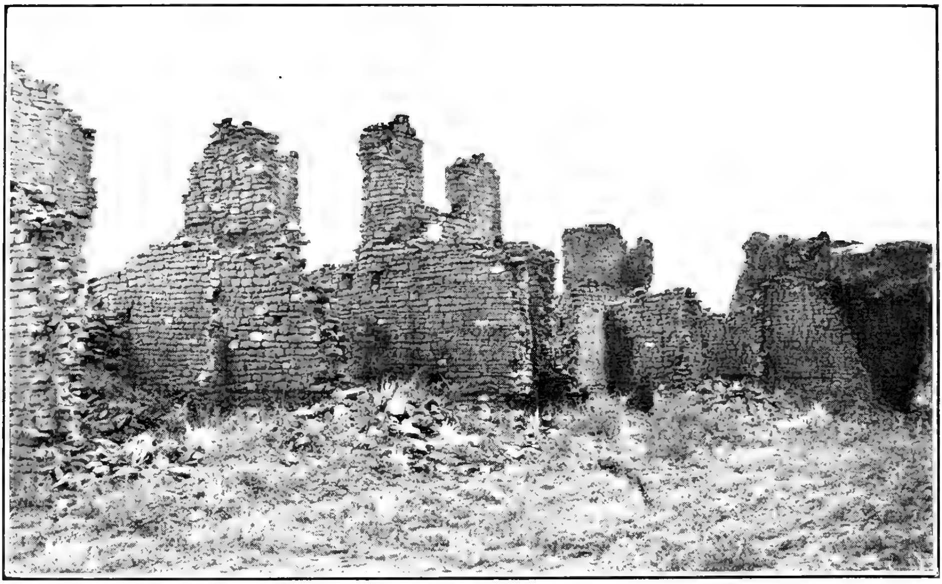

FIG. 1.—RUINS OF KINKLETSOI, CHACO CANYON, NEW MEXICO.

FIG. 2.—CLIFF DWELLING, MESA VERDE PARK, COLORADO.

the admission of New Mexico and Arizona as States, about 23,000,000 acres of public lands within their borders will pass to those Commonwealths, and their legislatures will have to be invoked for the protection of ruins thereon. There are few, if any, remaining cases where it is desirable that agricultural or otherwise useful lands should be withheld from preemption or other disposal because of the ruins situated upon them. Where such cases do exist, it would be possible for the General Land Office, if informed by recognized authority, to withhold by temporary withdrawal the smallest acreage adequate to the protection of the buildings, cemeteries, etc., until excavated and reported on, after which the tracts should be released. There are several important isolated sites and some important districts situated on lands completely worthless for agricultural or other economic purposes which should be withdrawn by the General Land Office, since any preemption of them would be solely for the purpose of securing possession of the antiquities thereon in violation of the spirit of the land laws. Cases in point are the Chaco Canyon ruins, in northwestern New Mexico, and those of Montezuma Mesa, southwest of Acoma. The status of ruins on public lands, as that term is here used, in not at all satisfactory. The General Land Office has done what was possible by way of withdrawal and recommendation for Congressional action in cases of exceptional importance in which no economic interests were involved, and has prohibited unauthorized excavation, but it has been ruled that under no existing provision of law can funds be used to pay for custodianship. Accordingly the protection afforded must of necessity be inadequate. A slight amendment to the sundry civil bill would remedy this.

Those of the sixth class, situated on lands withdrawn from entry or other disposal for special purposes, are very numerous, as may be seen from the list of important districts and sites. It is to be hoped that all in this class may be speedily transferred to classes 1 and 2, as contemplated by their withdrawal. With the establishment of Pajarito National Park and the Jemez and Taos forest reserves the efficient and permanent protection of a large proportion of the most important of the ruins of the Rio Grande drainage will be assured. The creation of the Mesa Verde National Park and saving, by withdrawal, of as many of the Chaco Canyon pueblos as are on lands still open to preemption, would insure the preservation of a fair proportion of the important sites of the San Juan drainage. With the establishment of the Rio Verde forest reserve all the great groups of the Gila drainage will have been brought incidentally under adequate permanent custodianship. The status of ruins of the sixth class is more satisfactory than those of the fifth. They are preserved from alienation by preemption or other disposal and warning notices

are kept posted thereon, prohibiting injury and unauthorized excavations, but these lands are not policed for the same reason that those of class 5 are not. However, the orders of the Department of the Interior have been effective to a great extent and ruins on withdrawn lands are suffering but little from vandalism.

The seventh class, those situated on State lands, is inconsiderable at present, but with the admission of the Territories and subsequent segregation of their lands this class will require consideration. As segregation will not, as a rule, be in large areas, but by single sections, large districts of ruins will not be affected, but important isolated sites will be, and the State governments should then be invoked to exercise protective authority over them.

The eighth class, those on private lands, includes many important sites. The number of private land grants, in New Mexico especially, is very large, and some of them are covered with important ruins. Many are on railroad selections and some on small holdings or homesteads. Some owners of homesteads and grants realize the importance of preserving these ruins for scientific research and exercise due custodianship over them. Others use the stones for building material, and timbers, if any, for firewood.

The above is as comprehensive a presentation of the status of archeology in the pueblo region as I am capable of making within the limits set for this paper. It is based on many years of personal residence and field work in the Southwest, in connection with the researches of all other investigators of the pueblo field, the results of which I have freely availed myself of. During the past six months I have had the opportunity to give considerable attention to the phases of the subject dealt with in this paper, for which the resources of the General Land Office, the Office of Indian Affairs, the Bureau of Forestry, and the Bureau of Amercian Ethnology have been most cordially placed at my disposal. I feel that my conclusions are at least not hastily drawn.

V. Synopsis of Important Districts and Sites.

In this arrangement I have endeavored to point out only those archeological districts and special sites which, by reason of their character, situation, state of preservation, or ethnic significance, are particularly worthy of investigation. The list is by no means a complete one. Doubtless many are omitted that are as important as those named, and it is to be remembered that every aboriginal site or object is of sufficient importance to warrant investigation.

In order to indicate, when known, how the various sites are located with reference to jurisdiction, I have used the following abbreviations:

Nat. Res., situated on national reservation or park.
For. Res., situated on forest reserve.
Ind. Res., situated on Indian reservation.
Mil. Res., situated on military reservation.
Pub. L., situated on public lands.
With. L., situated on withdrawn lands.
Pri. L., situated on private lands.

The asterisk is used to indicate sites of sufficient importance to demand permanent preservation.

I.—THE RIO GRANDE DRAINAGE.

1. In Upper Pecos Valley:
    * Pecos, Ind. Res.
    Seyupa.
    Tonchun.
    San Antonio.
2. About the Salt Lakes of the Manzano:
    * Tabira (Gran Quivira) Pri. L.
    Quarra.
    Abo.
    Tajique.
3. In the Galisteo Basin:
    Yamphamba (San Cristobal).
    Ipera (San Lazaro).
    Tagewinge (Galisteo).
    Hishi (Pueblo Largo).
4. In the San Pedro Basin:
    Tunque.
    Paako or Kukua, Pri. L.
5. In the Santa Fe Basin:
    Tsinatay (La Bajada).
    Tsiguma (La Cienega).
    Kuaka.
    Kuapoge (Ft. Marcy) Mil. Res.[a]
6. In the San Ildefonso Basin:
    Sacona, Ind. Res.
    Kyamunge, Ind. Res.
7. In the main valley of the Rio Grande:
    Katishtya (Old San Felipe) Ind. Res.
    Perage (Old San Ildefonso) Ind. Res.
    Puaray.
    Kuaua.
8. In the Chama Basin:
    Tsawari.
    Houiri, Pri. L.
    Sepawi.
    Homayo, Pri. L.
9. The Taos region[b] With. L.:
    Numerous sites in the vicinity of Taos and Picuris.

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[a] Ceded to the city of Santa Fe.

[b] This is partly included in the lands withdrawn for the proposed Taos Forest Reserve.

The majority of the above (1 to 9) are sites occupied within the last four centuries and abandoned at intervals from the time immediately preceding the Spanish occupation down to 1838. The years immediately following 1680 were particularly disastrous to the Rio Grande Pueblos. Archeological research at these sites should be fruitful in throwing light upon the first influences of the exotic civilization upon the indigenous tribes. They are all ruins of considerable magnitude, but in many cases reduced to mounds.

10. * Pajarito Park,[a] With. L.:
  Shufinne.
  Otowi.
  Puye. (Plate I, fig. 1.)
  Tsankawi.
  Cliff dwellings of Shufinne Mesa.
  Cliff dwellings of Puye Mesa.
  Cliff dwellings of Chupadero Canyon.
  Cliff dwellings of Sandia Canyon. (Plate I, fig. 2.)

This is strictly a prehistoric district and archeologically one of the richest in the Pueblo region. The cliff dwellings are of the excavated type and exist in vast numbers, almost every southern escarpment being honeycombed with them. Besides the identified pueblo ruins named, several others of almost equal importance and hundreds of minor ones are scattered over the district. The permanent reservation of this tract will preserve intact a fairly complete exhibit of the prehistoric civilization of the Rio Grande Valley. This is now assured, for it falls within the limits of the proposed Rio Jemez Forest Reserve, and will in due time come under the custodianship of the Bureau of Forestry if it does not become a national park. The only collections that have been made from this district are in the museum of the New Mexico Normal University at Las Vegas.

11. On Ramon Vigil Grant,[b] Pri. L.:
  (Tewa; Tchire, bird; ge, house = house of the bird people: Spanish, Pajarito, a little bird.)
  * Tchirege. (Plate II.)
  Cliff dwellings of Pajarito Canyon.
  Navakwi.
  Numerous large and small pueblos of Mesa del Pajarito.

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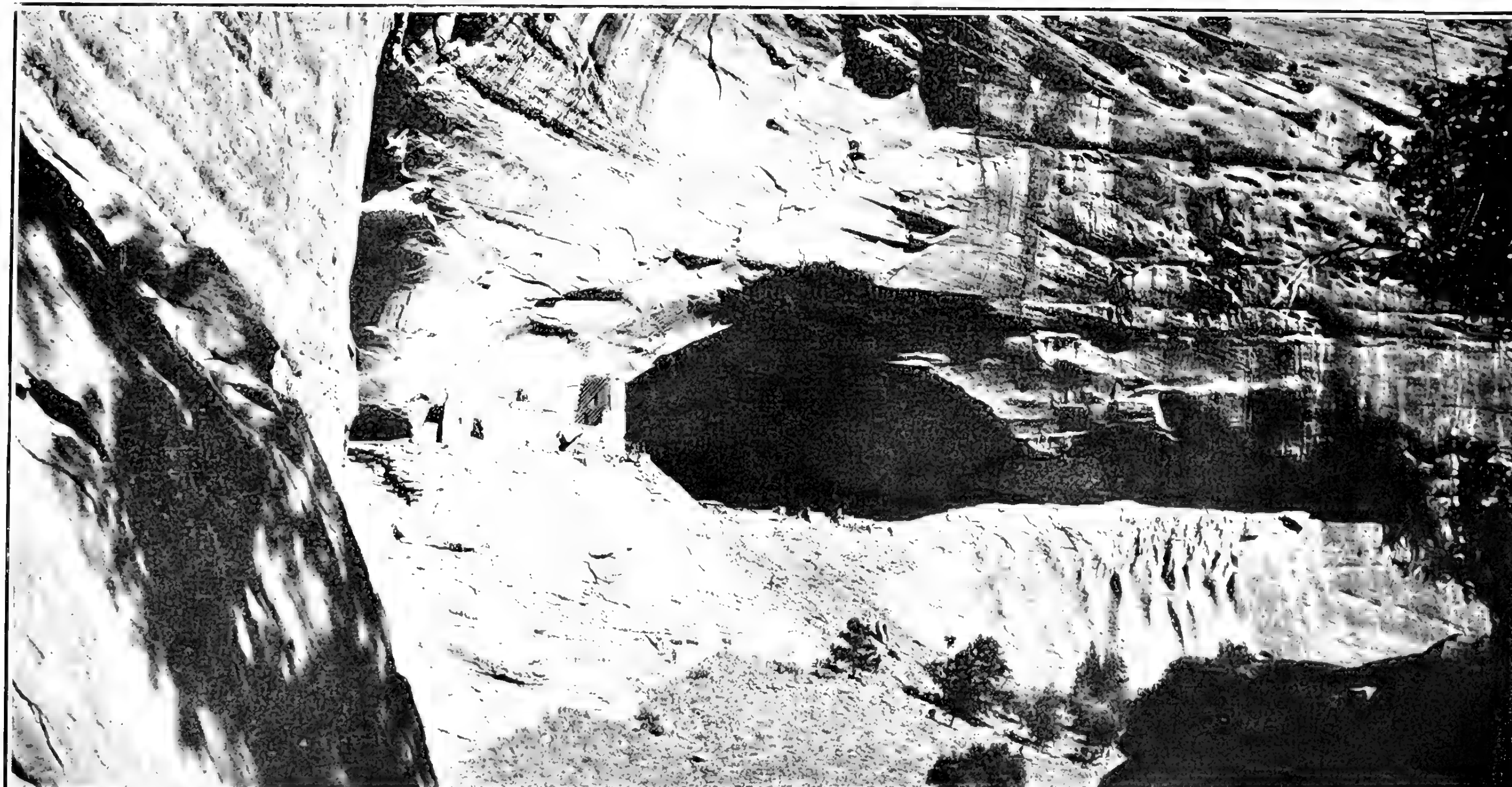
[a] I here restrict the name Pajarito Park to the district 10 miles long by 4 wide that is under withdrawal and consideration for a national park. (H. R. 7269, 58th Cong.) As originally proposed and withdrawn, it was much more extensive, and received its name from what was the central geographical feature of the entire district, viz, Pajarito Canyon. This has since been found to be largely on Ramon Vigil Grant, which was almost surrounded by the proposed park. As the lines are now drawn, it creates Pajarito Park with the "Pajarito" left out.

[b] This is the original Pajarito Park. The value of the ruins is appreciated by the owners and they are under proper custodianship.

CASA BLANCA, CANYON DE CHELLY, ARIZONA.



CLIFF DWELLING AND MUMMY CAVE, CANYON DEL MUERTO, ARIZONA.

12. Cochiti district,[a] With. L.:
    * Tyuonyi.
    Pueblo Viejo.
    * La Cueva Pintada.
    Haatse.
    Kuapa.
    * Stone lions of Potrero de las Vacas.
    * Cliff dwellings of Rito de los Frijoles.
    Cliff dwellings of Cañada de la Cuesta Colorada.
13. In upper Jemez Valley,[b] With. L.:
    * Giusewa and Mission Church of San Diego. (Plate III.)
    Large number of important pueblo ruins in valley and on adjoining mesas.
14. In the San Jose Valley:
    San Mateo, Pri. L.
    Cubero, Ind. Res.
15. * In Cebolilto Valley and Montezuma Mesa, Pub. L.:
    A large number of important pueblo sites unnamed. (Plate IV.)
16. In the Magdalena region, Pub. L.:
    A number of important pueblo sites unnamed.

II.—THE SAN JUAN DRAINAGE.

1. * In Chaco Canyon:
    Pueblo Pintado, Pub. L.
    Wejiji (Kindoklis), Pub. L.
    Hungopavi,[c] Pri. L. (Plate V, fig. 1.)
    Una Vida,[c] Pri. L.
    Chettrokettle,[d] Pri. L.
    Pueblo Bonito,[d] Pri. L.
    Casa Rinconada,[d] Pri. L.
    Pueblo del Arroyo[d] (Tabakin), Pri. L.
    Kinkletsoi, Pub. L. (Plate VI, fig. 2.)
    Casa Chiquita, Pub. L.
    Pueblo Alto, Pub. L.
    Penasco Blanco (Talakin), Pri. L.
    Sinkletzin,[c] Pri. L.

This is unquestionably the finest and best preserved group of pueblo ruins on American soil. It is a matter of great regret that the General Land Office was not invoked in time to preserve intact

[a] I apply this name to the district north of Cochiti, which embraces the ruins of the former habitations of the Cochiti Indians. It was included in the original withdrawal for the proposed Pajarito National Park, but is omitted from the bill (H. R. 7269, 58th Cong.) creating the same. It includes the lovely Rito de los Frijoles of Bandelier and Lummis. It is fortunately included within the limits of the proposed Rio Jemez Forest Reserve.

[b] These ruins are upon the lands withdrawn for the proposed Rio Jemez Forest Reserve.

[c] These pueblos are on railroad lands to which title has passed irrevocably.

[d] These are on the homestead of Mr. Richard Wetherill. This homestead has been suspended by the General Land Office and entry may be canceled.

this remarkable group of prehistoric buildings with all their auxiliary remains when it could have been done by the withdrawal of the entire tract. This is no longer possible, since every alternate section is now patented railroad land. The central group of ruins, i. e., Pueblo Bonito and its environs, have passed to private ownership unless annulled by the General Land Office. This tract of country is absolutely worthless for any economic purpose. The fate of the great body of ruins situated here is a striking illustration of the need for comprehensive legislation on this subject. This loss to science and history is solely the result of there being no one whose business it is to look after such matters. Through the generosity of the Messrs. Hyde, of New York City, a splendid collection obtained by the partial excavation of Pueblo Bonito is preserved in the American Museum of Natural History in New York City.

2. On tributaries of Chaco Canyon, Pub. L.:
   * Kinklizhin. (Plate V, fig. 2.)
   * Kinyaah.
   * Kinbiniola.
   Kinahzin.

These buildings are of the same class and state of preservation as those of Chaco Canyon and probably belong with them ethnically.

3. In Cañyon de Chelly and its tributaries, Ind. Res.:
   Cliff dwellings and pueblos of Canyon de Chelly. (Plate VII.)
   Cliff dwellings and pueblos of Canyon del Muerto. (Plate VIII.)
   Cliff dwellings and pueblos of Monument Canyon.

This is a remarkable group, consisting of a large number of pueblos and pueblo-like cliff dwellings in an excellent state of preservation, and being on an Indian reservation, under a custodian, their protection is assured. A large collection from this region is in the museum of the Brooklyn Institute of Arts and Sciences.

4. * In the Mesa Verde region,[a] Ind. Res. and With. L.:
   Cliff Palace. (Plate IX.)
   Balcony House.
   Cliff dwellings of Mancos Canyon.
   Cliff dwellings of Navaho Canyon.
   Spruce Tree House.
   Long House.
   Cliff dwellings of Ruin Canyon.
   A large number of ruined towers.

This is the most remarkable group of pueblo-like cliff dwellings in existence. They are in a good state of preservation. The protection of these ruins is assured. They present the best picture we have of

[a] I include in this title not only the cliff dwellings that are situated on the tract withdrawn for the proposed Mesa Verde National Park, but also those on the southern Ute Indian Reservation south to and including Mancos Canyon, all of which should be included within the park limits.

that phase of Pueblo culture which took advantage to the greatest possible extent of the protection afforded by a cliff environment, regardless of the hardships incident to such an existence. Many of these dwellings are almost inaccessible. This will be one of the most instructive and attractive of all our national parks. Unfortunately, the collections that have been made from these ruins are badly scattered and not well authenticated.

5. In Las Animas Valley:
   * The Aztec ruin,[a] Pri. L.
6. In Aztec Springs Valley:
   Aztec Springs ruin.
7. In La Plata Valley:
   La Plata ruin.
8. In the main valley of the San Juan:
   Solomon's Ruin, Pri. L.
9. In the vicinity of Bluff, Utah:
   Ruins of McElmo Canyon.
   Ruins of Hovenweep Canyon.
   Ruins of Montezuma Canyon.
   Ruins of Yellowjacket Canyon.
   Ruins of Cottonwood Canyon.

These are very numerous pueblo and cliff-dwelling ruins, mostly unnamed sites in an indifferent state of preservation, but archeologically very important. Some interesting collections from these ruins are in the American Museum of Natural History in New York.

III.—THE LITTLE COLORADO DRAINAGE.

1. On the Tusayan plateau, Ind. Res.:
   (*a*) In Oraibi wash—
      Kwaituki.
      Seven-Mile Ruin.
   (*b*) Middle Mesa group—
      Old Mashongnavi.
      Old Shumopavi.
      Payupki.
      Chukubi.
   (*c*) East Mesa group—
      Sikyatki.
      Kukuchomo.
      Kisakobi.
      Tukinobi.
   (*d*) In Jettyto Valley—
      Awatobi.
      Kokopnyama.
      Kawaika.
      Chakpahu.
   (*e*) In Cottonwood wash—
      Bidahuçi group.
   (*f*) Miscellaneous—
      Tebugkihu (Fire House), northeast of Keams Canyon.

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[a] Properly cared for by the owner, Mr. Kountz.

2. In the main valley of the Little Colorado:
   Homolobi.
   Chevlon.
3. In the Puerco Valley:
   Adamana.
   Navaho Springs.
   Kintiel (30 miles north of river), Pri. L.
4. In the petrified forest, With. L.:
   Stone Ax.
   Canyon Butte Ruin.
   Milky Wash Ruin.
5. In Chavez Pass:
   Tchubkwitcala.
6. In the Silver Creek Valley:
   Four-mile ruin.
   Pinedale.
   Showlow.
   Linden.

The above groups of ruins of the Little Colorado Drainage (1 to 6) are all pueblo sites that have proven to be of great archeological interest. Some of them are known to have been inhabitated during the historic period. They have suffered much from indiscriminate, unscientific excavation and collections therefrom are badly scattered and not well authenticated. On the other hand, a great amount of scientific work of the highest order has been done in these ruins and excellent collections from them are in the United States National Museum, the Field Columbian Museum, Chicago, and Peabody Museum, Cambridge.

7. On the Zuñi Region, Ind. Res.:
   * Hawikuh.[a]
   * Kiakime.[a]
   * Halona.[a]
   * Matsaki.[a]
   Pinaua.
   Ketchipauan.
   * Chyanaue.[a]
   * Archeotekopa, Pub. L.
   El Morro or Inscription Rock, With. L.

These are historically the most important ruins in the United States, embracing the remains of the famous "seven cities of Cibola" and many other pueblo sites of equal magnitude. Many are in a fair state of preservation, some reduced to mounds; but it will be generally agreed, I believe, that all remains of this historic group, whatever may be their condition, merit preservation. Being under custodianship, they should suffer but little from vandalism. Large collections from these ruins are in the Peabody Museum, Cambridge, the results of excavations by the Hemenway expedition.

[a] Identified by Bandelier and Cushing as belonging to the "seven cities of Cibola."

CLIFF PALACE, MESA VERDE PARK, COLORADO.

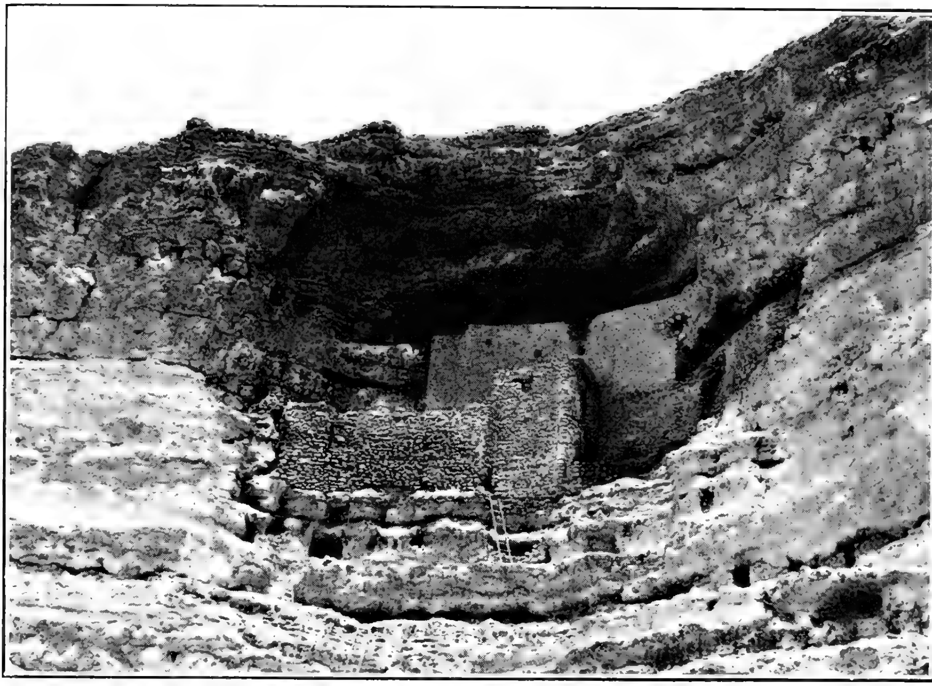


FIG. 1.—MONTEZUMA CASTLE, BEAVER CREEK, ARIZONA.

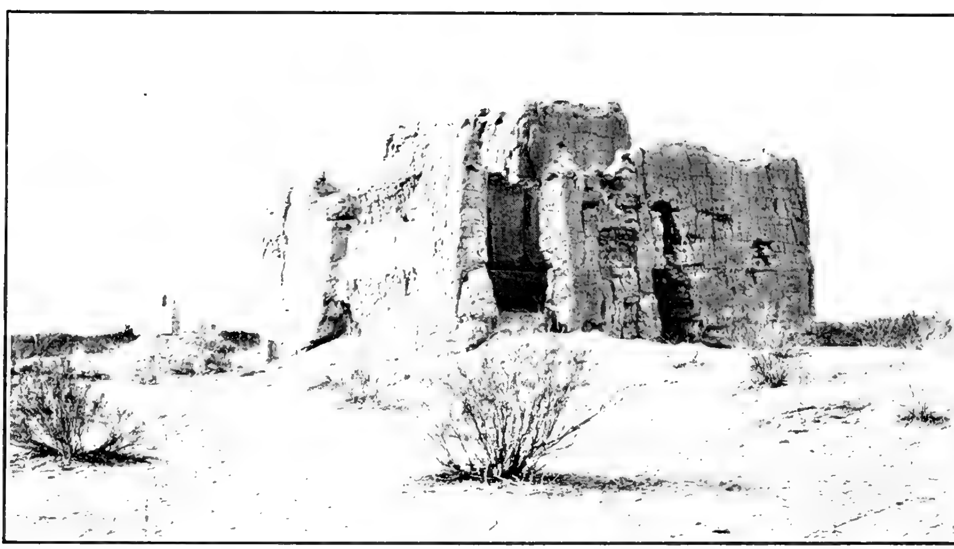
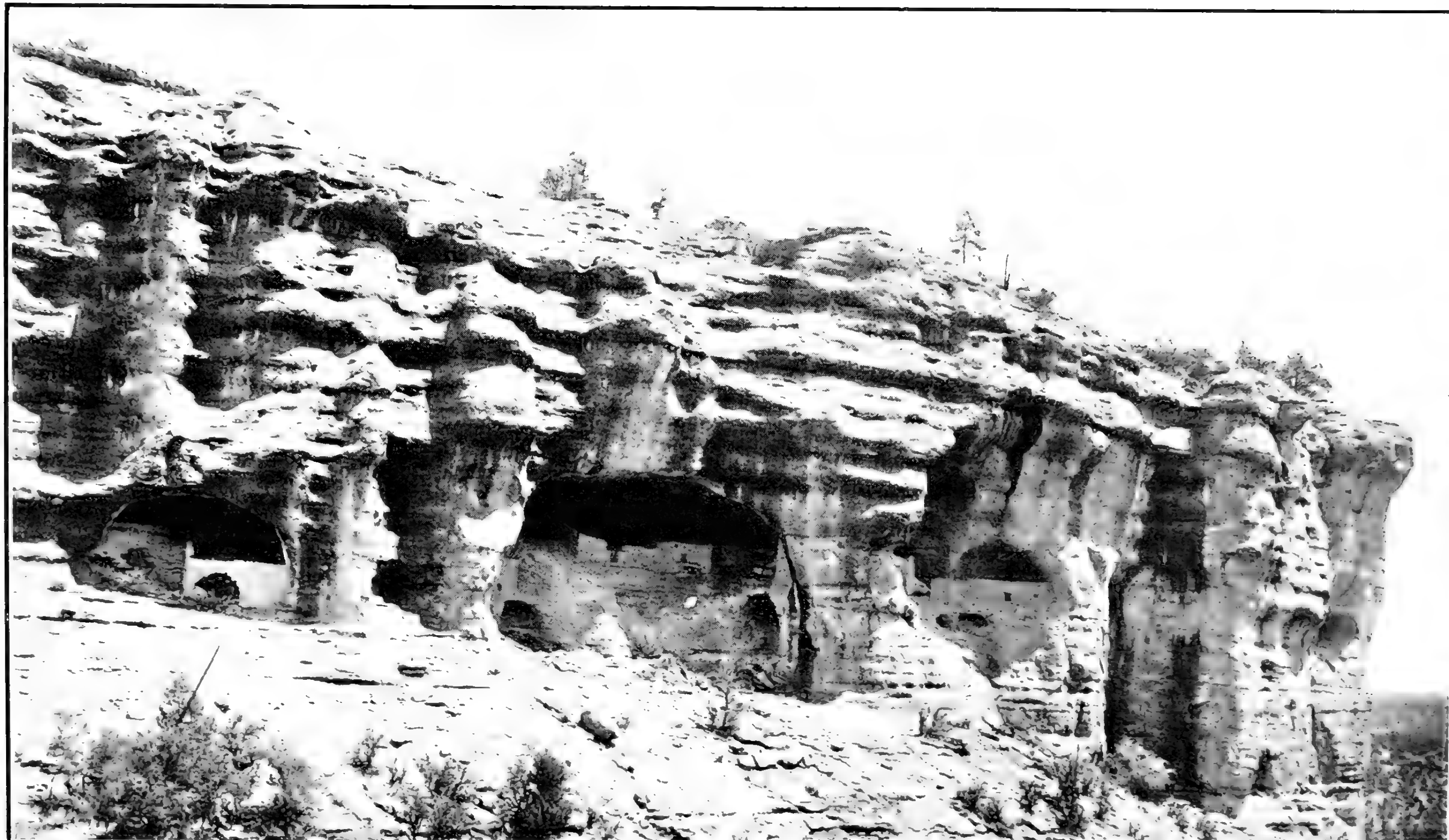


FIG. 2.—CASA GRANDE, GILA VALLEY, ARIZONA.



CLIFF DWELLINGS, GILA HOT SPRINGS, NEW MEXICO.

8. * In Walnut Canyon, For. Res.
   A fine group of cliff dwellings.
9. On Cave Dwellers Mountain, For. Res.:
   An extensive and interesting group of cave dwellings.
10. The Black Falls Region, For. Res.
    Several important groups of pueblo ruins in a good state of preservation; not named.

IV.—THE GILA DRAINAGE.

1. In the Verde Valley:
   (*a*) In the main valley, With. L.—
      Great number of excavated cliff dwellings.
   (*b*) * The Red Rocks district—
      Honanki.
      Palatki.
      Many other unnamed pueblo and cliff-dwelling sites.
   (*c*) * Beaver Creek—
      Montezuma Castle, With. L. (Plate x, fig. 1.)
      Montezuma Well, For. Res.
2. In the Salt River Valley:
   (*a*) In the Tonto Basin, With. L.—
      Numerous pueblos and cliff-dwelling sites.
   (*b*) On White Mountain Creek, Ind. Res.—
      Numerous pueblo and cliff-dwelling sites.
3. In the main valley of the Gila:
   * Casa Grande, Nat. Res. (Plate x, fig. 2.)
      Pueblo Viejo.
      Numerous unnamed sites.

These pueblos have been rapidly destroyed by the advance of agriculture, most of them without scientific investigation. Important explorations were made by the Hemenway expedition among the lower Gila ruins, the collections from which are in the Peabody Museum, Cambridge.

4. * On the upper tributaries of the Gila, For. Res.:
   (*a*) On the Blue—
      Numerous cliff-dwelling and pueblo sites.
   (*b*) On the San Francisco—
      Numerous cliff-dwelling and pueblo sites.
   (*c*) On the Tularosa—
      Numerous cliff-dwelling and pueblo sites.
   (*d*) On the west fork of the Gila—
      Gila Hot Springs cliff dwellings. (Plate xi.)

The ruins of the upper Gila and its tributaries are among the most important and least known in all the pueblo region. Many are in an excellent state of preservation. But little in the way of scientific study has been done among them and no extensive collections have yet been made. Fortunately, efficient custodianship has been extended over them in time to secure them while still in a good state of preservation.

   (*e*) On the San Pedro—
      Numerous pueblo ruins.

V.—MISCELLANEOUS.

1. In the Mimbres Valley.

This is, strictly speaking, an inland drainage, tributary to neither the Rio Grande nor the Gila, between which it lies, and extending down into the State of Chihuahua, Mexico. In this valley is a large number of interesting pueblo sites.

2. In Lost Canyon, Colorado.

In this and other tributaries of the Dolores drainage are numerous cliff dwellings and towers, remarkable as being the one point where pueblo culture of any importance extends north of the San Juan-Grand watershed.

3. In the Virgin Valley, Utah.

A locality of numerous pueblo ruins, remarkable as being the only ones of much note west of the Colorado River.

4. On the military reservations of Fort Bayard, Fort Wingate, Fort Lowell, Fort Apache, Camp Verde, and Fort Defiance are ruins of considerable importance, including cliff dwellings, pueblos, towers, and cemeteries not specifically pointed out in the drainage areas in which they occur.

VI. Conclusion.

It is manifestly time for decisive action on the question of American antiquities. Congress should at once enact comprehensive legislation on this subject. It is the duty of those interested in American archeology to prepare the necessary information and present it to the proper authorities in such manner that the scope of legislation needed will be self-evident. I offer the following suggestions, which I believe, in the light of our present information, to be in accord with the views of a large majority of the archeologists dealing with American subjects and acquainted with the American field:

1. That the preservation of antiquities on all lands owned or controlled by the Government of the United States should be provided for by law.

2. That custodianship of antiquities should be left where it is, viz, in the departments having jurisdiction over the lands on which antiquities are situated, and that the protection of said antiquities by said departments should be made obligatory.

3. Expert authority should exist for the periodical inspection of ruins, report on the same, and recommendation of preservative measures to the departments having custodianship.

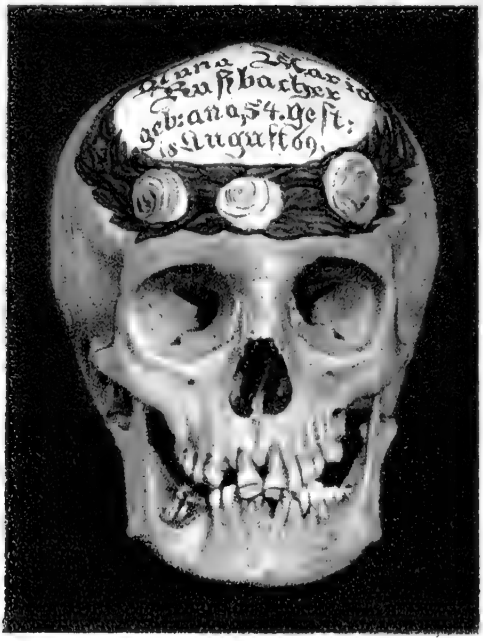
4. The privilege of excavation should be restricted to institutions, domestic or foreign, that can conduct the same in a scientific manner and make report of results, and that will place all collections secured in permanent public museums.

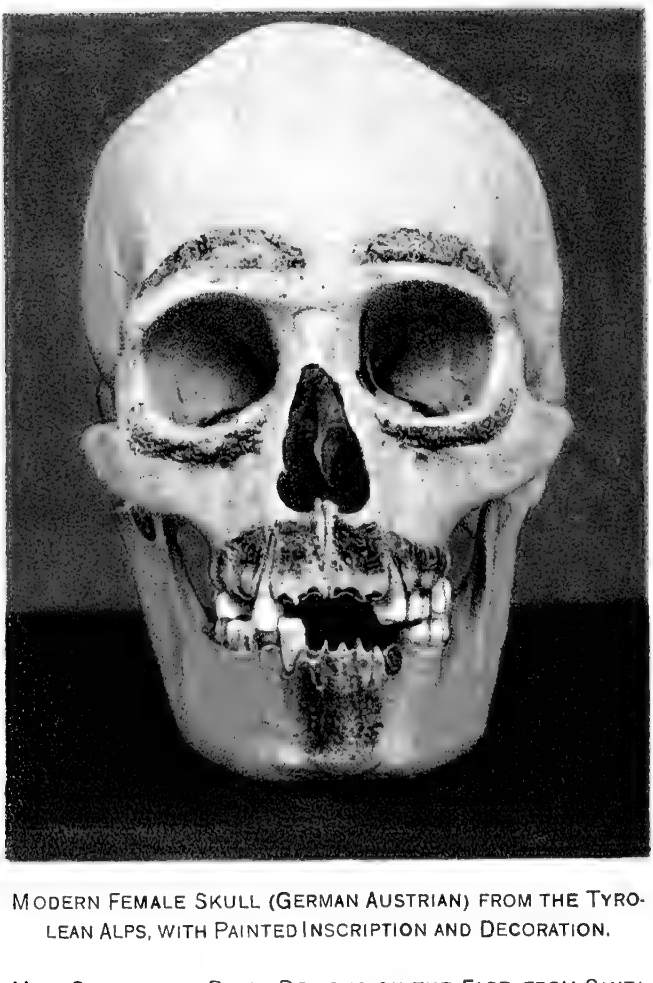
5. There should be expert inspection of excavations, to see that the

same are conducted according to the regulations prescribed, and to see that collections are disposed of as provided for by law and not for commercial purposes.

6. Adequate penalties for violation of the law should be prescribed

In the meantime it is unnecessary to await the movement of the great machinery of Congress when so much power already exists in Executive Departments and so much loss goes on that future Congressional action can never repair. Results can be steadily accomplished. Departments invite authentic information and recommendations. When furnished with evidence they act promptly and effectively. All who are interested in the preservation of American antiquities—and this is a rapidly growing number—should encourage and uphold these efforts in every possible way.





MODERN FEMALE SKULL (GERMAN AUSTRIAN) FROM THE TYROLEAN ALPS, WITH PAINTED INSCRIPTION AND DECORATION.

MALE SKULL, WITH BLACK DESIGNS ON THE FACE, FROM SANTA CRUZ ISLAND, CALIFORNIA.

THE PAINTING OF HUMAN BONES AMONG THE INDIANS.[a]

By Aleš Hrdlička.

Painting of human bones is one of the ethnic phenomena of a relatively high differentiation found unaccountably in various, widely separated parts of the world; and the custom has probably existed in prehistoric as well as historic times. Painted skulls or bones have been found in the York Islands (Finsch), in Polynesia, and among the Papuans, in Australia (W. Krause), New Zealand (Thilenius, Martin), and Andaman Islands. A skull of a child (No. 164763, U. S. National Museum) from the Andaman Islands shows on the vault, bilaterally, a geometrical design, including a line of connected diamond-shaped figures, in red paint; and on the vault of an adult female skull (No. 164765, U. S. National Museum), from the same locality, are four lines, running from before backward, of similar but smaller diamond-shaped figures painted in white. Bones covered more or less by red pigment—in many instances it has not been definitely settled whether intentionally or accidentally—are very common in the older kourgans over large regions in Caucasus and southern Russia (Vasselovski, Antonovitch, Zaborovski, Spizyn, and others), in Moravia (Makovsky), Bohemia (Matiegka), Switzerland (Martin), Italy (Pigorini), France (d'Acy, Piette, etc.), and Germany (Krause). A curious habit of placing inscriptions of name, date of birth and date of death of the person upon the skull, and surrounding this with a hand-painted design, has existed until recent years in the Tyrolean Alps. The U. S. National Museum possesses three examples of such skulls (from Professor Kollman, in Basel), one of which is here illustrated (fig. 1, pl. I), and I have seen a number of others in Professor Zuckerkandl's collection in Vienna.

On the American continent bone painting has been reported by some of the old chroniclers, as well as some modern students. I

[a] Modified, with some additions, from the author's A Painted Skeleton from Northern Mexico, with Notes on Bone Painting among the American Aborigines, printed in American Anthropologist, n. s., vol. 3, Sept.–Dec., 1901, pp. 701–725.

shall mention both later on. It existed, in more or less separated localities, in South America, as well as in North America and in Mexico.

The subject has been repeatedly brought to my attention in examining Indian bones in our various museums, and is so closely and in several ways associated with various modes of accidental bone staining that the two must, to a certain extent, be treated together.

All pigmentation of human bones, including painting, is divisible into five varieties.

The first variety, which is quite common, includes the skeletons that have been more or less stained or infiltrated accidentally by the coloring matter of the earth in which they have lain. As pronounced examples of this variety of staining I may mention the bones of a part of Mr. Bandelier's collection from Bolivia (A. M. N. H.), which are thoroughly stained and infiltrated by red clay. The accidental staining is mostly reddish or yellowish, but it may be dark, as was observed by Professor Putnam in certain burial places in Tennessee, and as can also be seen in a number of Florida skulls in the American Museum, and in the Costa Rica crania recovered from a deposit of volcanic ashes, now in the Carnegie Museum. Usually in these cases all the bones of the body are colored, and with little difference in intensity. The cavities of the skull show the same or nearly the same coloring as the parts more exposed.

The second variety of stained bones consists generally of skulls which had been stained green by salts of copper. These salts resulted mostly from the decomposition of copper (or copper alloy) ornaments or implements buried with the bodies. The staining in these cases, as a rule, is but partial; the coloring is greenish and is deepest at the nearest points of contact with the decomposed articles. The copper salts discolor the skull even through the skin. There is in the National Museum a comparatively fresh female skull from Oregon (No. 150011), in which the borders of both orbits and some of the neighboring parts, though still covered by their skin, are green. On the closed eyelids of each eye are seen two circular impressions, apparently made by some coins pressed into that position; the copper salts resulting from the decomposition of these coins penetrated through the opening of the eyelids as well as through the skin and discolored the bone beneath. There is another specimen of allied nature in the collection from Utah. Green-stained skulls have been found in numerous localities on both parts of the continent, especially along the northwest coast. The Wasco skull here pictured shows a characteristic coloration of this nature (fig. 1, pl. II).

In the third and very frequent and widely distributed variety of stained bones, there is more or less staining of the skeleton by pigments which were buried with the body. In most cases known to me,

or of which I have found mention in literature, the coloration was red, and in most instances due to red ocher. In a few cases, probably more recent burials, the pigment was vermilion.

The fourth class of stained bones is much more restricted than any of the preceding; it consists mainly of skulls which had been painted by hand. In all but two cases known to me on this continent the paint was red, and was applied sometimes over the facial parts of the skull only, at other times over the whole cranium, and in a few instances also over other bones of the skeleton. I shall cite examples of this class from United States, Canada, and other regions.

The fifth and final variety of bone staining consists of skulls on which designs have been made in colors. Such specimens thus far found are few and they are probably all, or nearly all, recent.

A variety of red pigmentation of human bones by the products of pigment producing bacteria has been suggested by Krause; I have as yet come across no instance where such agency would appear probable. Blackening of bones is occasionally witnessed in maceration.

In a number of instances it is difficult, if not impossible, to decide whether the given bones have been stained accidentally by the pigment buried with the body, or whether they have been intentionally painted. It may be assumed, however, as a general rule, that where the coloration is symmetric, rather uniform in extent, and restricted to the external surface, not extending into the fossæ, ventral cavity, or even the alvoelar spaces of a skull, we have to deal with intentional painting of the specimen. In accidental staining the pigment is often found mixed with the earth about the bones, it covers the bones less regularly, and penetrates more or less into all the larger spaces. It is, of course, also possible that the paint applied to the bones by hand after their burial spreads somewhat by natural means to other parts, as well as to the soil, but in such instances the secondary coloration of the bone is liable to be restricted besides irregular, and the staining of the soil is very limited.

It is principally the last three varieties of pigmented bones which are, in this country each in a distinctive way, of ethnological interest, for they represent so many different, though probably related, customs of the American aborigines.

The geographical distribution of such stained or painted bones on this continent appears to be very wide, but so far is quite irregular. With the increase of material, some of the existing lacunæ will undoubtedly be filled, while in other cases there will be traced, according to indications, allied customs. On the whole it seems that one or another use of red pigment, particularly ocher, has been quite general in the funerary rites of the American Indians.

The deposit of pigments, particularly of ocher, in the shape of paint, with the bodies of warriors, and especially of chiefs, was very prevalent. Red paint was one of the Indian's necessities, and, with some of his other possessions, was buried with him as a part of his equipment for the future world or his journey thither. Lafitau (vol. II, 8, p. 413), in referring to the articles generally interred with the body of an Indian, mentions, among other things, "a quantity of oil and some color with which to paint himself." Loskiel (vol. II, p. 120) tells us that the Indians formerly "used to put a tobacco pouch, knife, tinder box, tobacco and pipe, bow and arrows (or a gun, powder, and shot), skins and cloth for clothes, paint, a small bag of Indian corn or dried bilberries, sometimes the kettle, hatchet, and other furniture of the deceased into the grave, supposing that the departed spirits would have the same wants and occupations in the land of souls as they had in this world. But this custom," Loskiel says, "is now (in 1794) almost entirely abolished in the country of the Delawares and Iroquois."

Among the Hurons, according to Sagard (Histoire du Canada, Paris, 1636, vol. III, p. 647), some paint was buried with the women, in order that in the other world they had enough to paint their robes with. Quantities of red ocher have been found in ancient Maine graves by Mr. C. C. Willoughby, of the Peabody Museum. Rev. J. M. Spainhour, in 1871, found in a mound on St. Johns River, North Carolina, three skeletons, and with each a quantity of red pigment (Yarrow, p. 27.) According to Elliott (vol. I, 60) and Young (p. 142), "the first Europeans who came to Cape Cod found there in an Indian grave nice matting, a bow, a decorated and painted board, and two bundles of red powder, in which lay the bones of the buried."

Mr. Moorehead found red ocher, and in a few instances also yellow and white mineral paints, heaped, as he expresses it, on or near the hands or other parts of the body, in earth mounds in several parts of Ohio. Lewis and Clark (vol. I, p. 239) mention having found some red and blue paint with the cadaver of an Assiniboin female. Mr. H. I. Smith, of the American Museum of Natural History, unearthed a skeleton at Saginaw, Mich., which was covered with red pigment, the surrounding soil being of a totally different character. Dr. J. Walter Fewkes found vessels containing "yellow ocher, sesquioxide of iron, green copper carbonate, and micaceous hematite" in what was apparently the burial of a priest, at Awatobi, a ruin of a former pueblo the base of what was formerly the first mesa of the Hopi Indians, in northern Arizona, and he found similar pigments in graves at Sikyatki, another ruin in the same region; and examples of a similar nature could be multiplied.

Judging from the references to Indian mortuary customs made by various authors, there were apparently a large number of instances

in which, in addition to, or possibly without, the deposit of some pigment with the deceased, the body, or at least the face, was painted. If the pigment used was mineral in character, as was almost invariably the case, the probability of the bones becoming more or less stained by it after the flesh had decayed was very strong. The custom of painting the body is especially well described by Lafitau. Speaking of the Indians of New France, he says that among them every "cabane" had special individuals who took care of the deceased. Those who are thus employed "wash the body, oil it, and paint its face and head. * * * Sometimes the man while yet living announces his death, arranges a feast, and lets himself be washed, oiled, and painted, and bundled up still alive into the position which he is to have in the grave."

Loskiel gives similar information about the Indians of the Eastern States and Canada: "Immediately after the death the corpse is dressed in a new suit, with the face and shirt painted red, and laid upon a mat or skin in the middle of the hut or cottage." Charlevoix (vol. VI, p. 107) says that among the Canadian Indians "the dead man is painted, enveloped in his best robe, and, with his weapon beside him, is exposed at the door of his cabin in the posture which he is to preserve in the grave." Sagard (vol. III, p. 649), speaking also of more than one northeastern tribe and without mentioning any separately, says that "not only are the savages in the habit of painting their faces black when any of their relatives dies, but they paint also the face of the cadaver."

The Iroquois, according to La Potherie (vol. III, p. 9 et seq.), "visit from time to time the burial place, paint the half-rotten bodies, change their clothing, and rearrange them in the fossa." Morgan also mentions the face painting of the dead Iroquois.

All the nations of the upper Missouri, according to Perrin du Lac, painted the bodies of their dead warriors with red ocher. These tribes comprised the Ricaras, Mandans, Grosventres, Chugayennes, Sioux, Cayoroas, Tocaninambiches, Tokionakos, Pitapahatos, Padaws, Halisanes, Assiniboins, and Crows. The custom was witnessed among the Crows as late as 1870 by Col. P. W. Norris, superintendent of the Yellowstone Park (cited by Yarrow), and quite as late among the Dakotas by Surg. L. S. Turner, U. S. Army (also cited by Yarrow). "The work among the Dakotas," says Doctor Turner, "begins as soon as life is extinct. The face, neck, and hands are thick painted with vermilion or a species of red earth found in various portions of the Territory."

The Creeks practiced a similar custom,[a] and there are indications of the former existence of a similar habit among the Omahas.

Professor Boas and Mr. Swanton inform me that many of the

[a] Schoolcraft, Vol. V, p. 270.

tribes of the North and Northwest paint the faces of their dead. The use of other colors than red were observed, but the latter predominates.

As to the Southwest and Mexico information on this subject is very meager, but evidence points to similar practices.

Bone painting proper is comparatively rare, or at least much less common than the custom of paint interment and of the painting of various parts of the corpse. We meet with instances of bone painting proper in Ohio, Florida, and South Carolina, in the East; in California, and possibly in British Columbia, in the West and Northwest; and in Mexico, and a few parts of Central and South America.

In Ohio painted bones were found by Prof. F. W. Putnam (Turner group mounds) and by Mr. W. K. Moorehead. The latter writes [a] me on the subject as follows:

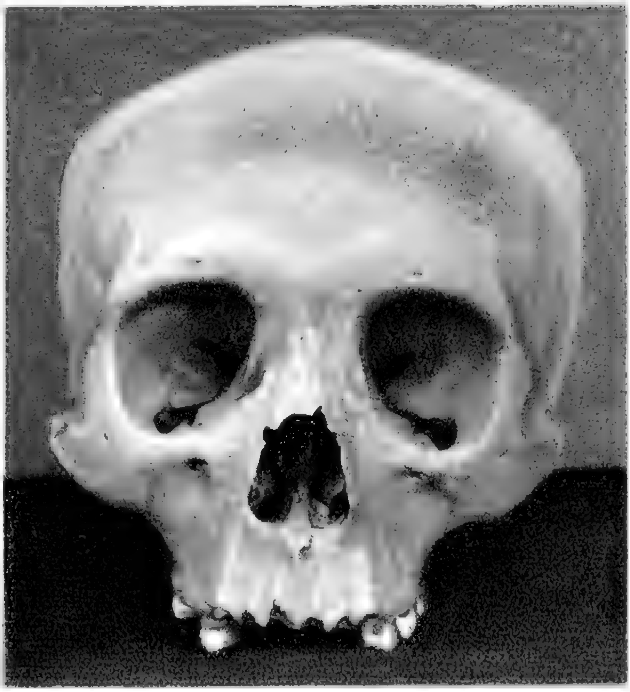
> Painted bones have been found in a mound at Omega, Ross County, Ohio; in Jackson County mound, Ohio, and in two mounds within the corporate limits of Chillicothe. One of the latter was discovered by Mr. Clarence Loveberry, assistant curator of the above [Ohio Archeological and Historical] society. The others were found by myself. Near Green Camp, Marion County, Ohio, in a stone grave 6 feet below the surface, Mr. Loveberry discovered a skeleton entirely painted.
>
> All of these were coated with red pigment or ocher, including in nearly every case all of the larger bones. There are other instances in which just the hands, or the feet, or perhaps the skull were coated. These are usually from mounds, either large or small. Bones on which the pigment was simply heaped were clearly distinguished by the surrounding soil being also stained.
>
> I have never observed instances in which skeletons were coated with yellow or black paints. (We have found yellow and white mineral paints near the hands of skeletons several times.)
>
> We have never found painted bones in stone mounds. They are invariably in earth mounds or stone graves.

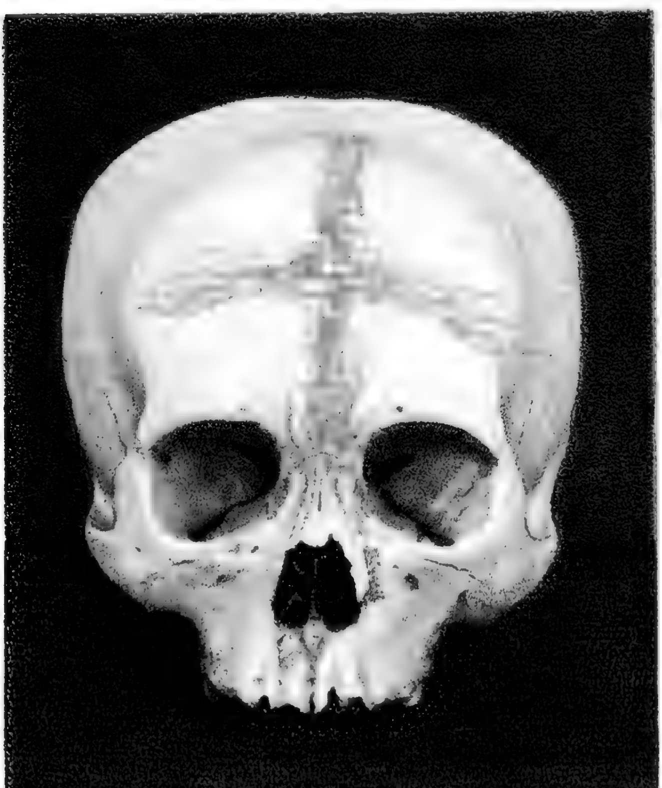
In South Carolina the custom is thus described by Lawson (pp. 21, 22):

> As soon as the party is dead they lay the corpse upon a piece of bark in the sun, seasoning or embalming it with a small root beaten to powder, which looks as red as vermilion; [b] the same is mixed with bear's oil to beautify the hair and preserve their heads from being lousy, it growing plentifully in these parts of America. After the carcass has laid a day or two in the sun they remove and lay it upon crotches cut on purpose for the support thereof from the earth; then they anoint it all over with the forementioned ingredients of the powder of this root and bear's oil. When it is so done they cover it very exactly over with bark of the pine or cypress tree, to prevent any rain to fall upon it, sweeping the ground very clean all about it.
>
> As soon as the flesh grows mellow and will cleave from the bone they get it off and burn it, making all the bones very clean; then anoint them with the ingredients aforesaid, wrapping up the skull (very carefully) in a cloth artificially woven with possum's hair. * * * The bones they carefully preserve

[a] Letter dated September 21, 1897.

[b] Sanguinaria?





WASCO SKULL, DISCOLORED BY DECOMPOSITION OF BRASS OR COPPER OBJECT BURIED WITH THE BODY.

WASCO SKULL, WITH COLORED CROSS OVER FRONTAL BONE.

in a wooden box, every year oiling and cleansing them; by these means preserve them for many ages, so that you may see an Indian in possession of the bones of his grandfather, or some of his relations of a longer antiquity.

In Florida bone painting seems to have been practiced extensively and from an early period. The custom is mentioned in this part of the country by Garcilasso de la Vega and by Herrera. Romans (p. 88) describes it among the Choctaw as follows:

The day [of the burial] being come, the friends and relations assemble near the stage, a fire is made, and the respectable operator, after the body is taken down [from the stage on which it has lain for two to four months], with his nails tears the remaining flesh off the bones and throws it with the entrails into the fire, where it is consumed; then he scrapes the bones and burns the scrapings likewise. The head being painted red with vermilion, is, with the rest of the bones, put into a neatly made chest (which for a chief is also made red) and deposited in the loft of a hut built for that purpose, and called "bone house." Each town has one of these. After remaining here one year, or thereabouts, if he be a man of any note, they take the chest down, and in an assembly of relations and friends they weep once more over him, refresh the color of the head, paint the box, and then deposit him to lasting oblivion.

An enemy and one who commits suicide is buried under the earth, as one to be directly forgotten and unworthy of the above ceremonial obsequies and mourning.

The late Andrew E. Douglass found what was possibly intentionally painted bones near St. Augustine, Fla.[a]

In certain parts of California the custom of bone painting seems to have been common.

Dr. H. F. ten Kate discovered several painted skeletons in Lower California (a cave on Espiritu Santo Island) and M. Diguet found others in the valley of Las Calaveritas. All the specimens from this part of the country were painted red. Those discovered by ten Kate were colored with ocher, while Diguet's specimens were decorated with a paint obtained from volcanic ashes. M. Diguet (p. 43) thought the localization of the burials in which painted bones are found was restricted to "the islands of Espiritu Santo and Cerralbo and a number of localities on the peninsula reaching in a straight line from the Gulf of California to the Pacific Ocean." The collections in the National Museum include one male adult skeleton (No. 148213, collected by E. Palmer), from the Espiritu Santo Island, Lower California, parts of which, especially the femora, show what appears to be intentional red painting. It is probable that from parts of this skeleton the paint, which looks like ocher, has been washed off. There is another male adult skeleton (No. 61398, collected by L. Belding), and a separate lower jaw,

[a] Sanchez Mound, situated about 8 miles north of St. Augustine. Over 20 bodies found. "Each cluster of bones was surmounted by the skull, and the whole mass encrusted with red paint, which discolored the sand an inch around them." (Proceedings Am. Assoc. Adv. Sci., 1882, XXXI, p. 587.)

from near La Paz, Lower California, every part of which shows intentional red painting, probably in ocher. The skull is here reproduced as a type of specimens of this nature (pl. III.) In a few patches on different parts of the skeleton the paint is nearly rubbed or washed off.

Professor Boas informs me that some red skeletons have been excavated near Thompson River in British Columbia, but it is not certain whether these bones were accidentally stained or intentionally painted. In the collection of the American Museum of Natural History is a skull (No. 99–1604) of a Clayoquot warrior from the west coast of Vancouver Island that is painted outwardly a very dark brown. There are other skulls from the Northwest in the collection of the American Museum that show red stains (particularly No. 99–3047, Copalis, west coast of Washington: Smith), but in these intentional painting is doubtful.

In Mexico I have never found any color stain on the bones in the territory of the Tarahumares; but a skeleton painted red with some vegetable dye and with traces of yellow, described by me before,[a] was obtained by C. Lumholtz just south of this region.

Several of the Tarasco crania from Michoacan (No. 99–175, for example) in the American Museum collection show red stains, but these may be accidental.

Finally, the American Museum collection includes several skulls and some bones of ancient Zapotecs and Mixtecs, collected by Mr. Saville in Oaxaca, and some of these show plain and indubitable signs of intentional painting with some inorganic red pigment, apparently ocher.

As to Central America and South America, one of the few references to the custom which I have noted concerns the Caribs, who according to Gumilla (Brinton's Myths of the New World, p. 225), about a year after death cleaned the bones of their dead, bleached them, painted them, and wrapped them in odorous balsams; they were then placed in a wicker basket which was kept suspended from the door of the dwelling. "When the quantity of these heirlooms became burdensome they were removed to some inaccessible cavern and stored away with reverential care."

The second instance pertains to the Bororos, one of the Amazon tribes, who, according to Ehrenreich, unearth the body about two weeks after death, clean the bones, paint them red, and additionally decorate the skull with red feathers. Von den Steinen, who witnessed the procedure among the Brazilian Indians with Ehrenreich, describes it thus:[b] "The observance lasts a whole day. The remains

[a] Amer. Anthropologist, n. s., vol. 3, Sept.–Dec., 1901, p. 701 et seq.

[b] Corresp. Bl. d. d. Gesellsch. f. Anthr., Ethnol., Urgesch., Dec., 1903, p. 176 (Arch. f. Anthrop., n. f. I, 4, 1904).

are unearthed eight to fourteen days after burial. The bones are thoroughly cleaned.' "They were brought and all parts of the skeleton were, before our eyes, painted red. They began with the skull. The whole was apparently a mode of decoration." 'The painted skull was additionally pasted over with red feathers. All the bones, skull included, were placed in a basket, which served for the final interment and which also received a coat of red, being in addition well covered with red feathers. The red pigment was a vegetable substance obtained from a certain seed."

I have thus far found no historical evidence of bone painting in Peru. There is no example of it among the over 200 Peruvian skulls in the National Museum. Among more than 500 ancient Peruvian crania of the Bandelier collection in the American Museum there is but one that shows distinct red stains, but these seem to be more accidental than otherwise. But in the more recent Gaffron collection in that museum there is a male adult skull, from the neighborhood of Cuzco (No. 99–3682), which shows over large portions of its surface a firm pink incrustation, in all probability the remnant of intentionally applied paint. According to E. Krause there is in the Reifs-Stübel collection of crania from Ancon, Peru, one of which the face is covered with "zinnober." [a]

The painting of designs on human skulls on this continent requires but few words. I have seen only five specimens of this sort and found no mention of others. Four of the crania, one from California, two Wasco from the Columbia River, and one from the Santa Cruz Island, California, are in the National Museum, and one found by Mr. H. I. Smith at Lytton, British Columbia, is in the American Museum of Natural History. The design on all but the Santa Cruz Island specimen consists of red, or in one of the Wasco skulls red and blue, cross made in very much the same manner (see fig. 2, pl. II). It is in all probability a recent work of some of the Christianized Indians. The Santa Cruz Island skull shows a partly faded, apparently ancient design, in black, above and under the orbits and on the maxillæ (see fig. 2, pl. I). A human skull, the vault of which has been cut off, while the remainder was painted with brown streaks and fitted into a stringed musical instrument, is preserved in the Metropolitan Museum of Art, New York, and was supposed to be of south American origin, but it came in all probability from Africa.

THE SIGNIFICANCE OF BONE PAINTING AMONG INDIANS.

Bone painting among the American aborigines is most probably a development of the custom of painting the corpse, just as the latter is an extension of the custom of painting the living. Paint.

[a] Globus, 19 Dec., 1901, p. 361; Verhandl. Berl. Anthr. Ges., 30, 285.

particularly red paint, was, and to some extent still is, among many American Indians, a part of the warrior's preparation for battle, and it was a mark of fitness, elevation, bravery, honor; and some of the tribes honored their distinguished dead, or even all their dead, with the same paint, applied in more or less the same manner in which it was used by the living. The bones of at least the naturally deceased friends were generally regarded with reverence.

According to Brinton (op. cit., p. 257) the opinion underlying all customs connected with the preservation of bones among various American people was "that a part of the soul, or one of the souls, dwelt in the bones; that these were the seeds which, planted in the earth, or preserved unbroken in safe places would in time put on once again a garb of flesh and germinate into living human beings. Language in some localities seems to strengthen this theory. The Iroquois word for bone is '*esken*,' for soul, '*atisken*,' literally that which is within the bone. (Bruyas, Rad. Verborum Iroquœorum.) In an Athapascan dialect bone is 'yani,' soul, 'i-yune.' (Buschmann, Athap, Sprachstamm, pp. 182, 188.)"

Yet there may have been instances in which the flesh or the bones of the dead were partly or wholly painted for other reasons. It is probable that in some instances the paint was considered a necessary or advantageous or proper equipment for the journey to the future world. Lafitau (vol. II, 8, p. 388) says that the Indians "applied the paint to the head and face in order that the horrors of death should not be seem." According to Boas, among the Chinook, who bury their dead mostly in canoes raised above the ground, after a time "the burial place is made good with red paint," which implies that in this tribe such paint is connected with some superstition. Finally, according to Bandelier, among the Muysca in Bogota, New Granada, bodies painted with red ocher were a sign of deep mourning. Judging from the general want among Indians of rational notions regarding the natural processes in the living or dead, it seems very improbable (though I formerly was inclined to think otherwise) that the paint was in any instance applied simply as a preservative.

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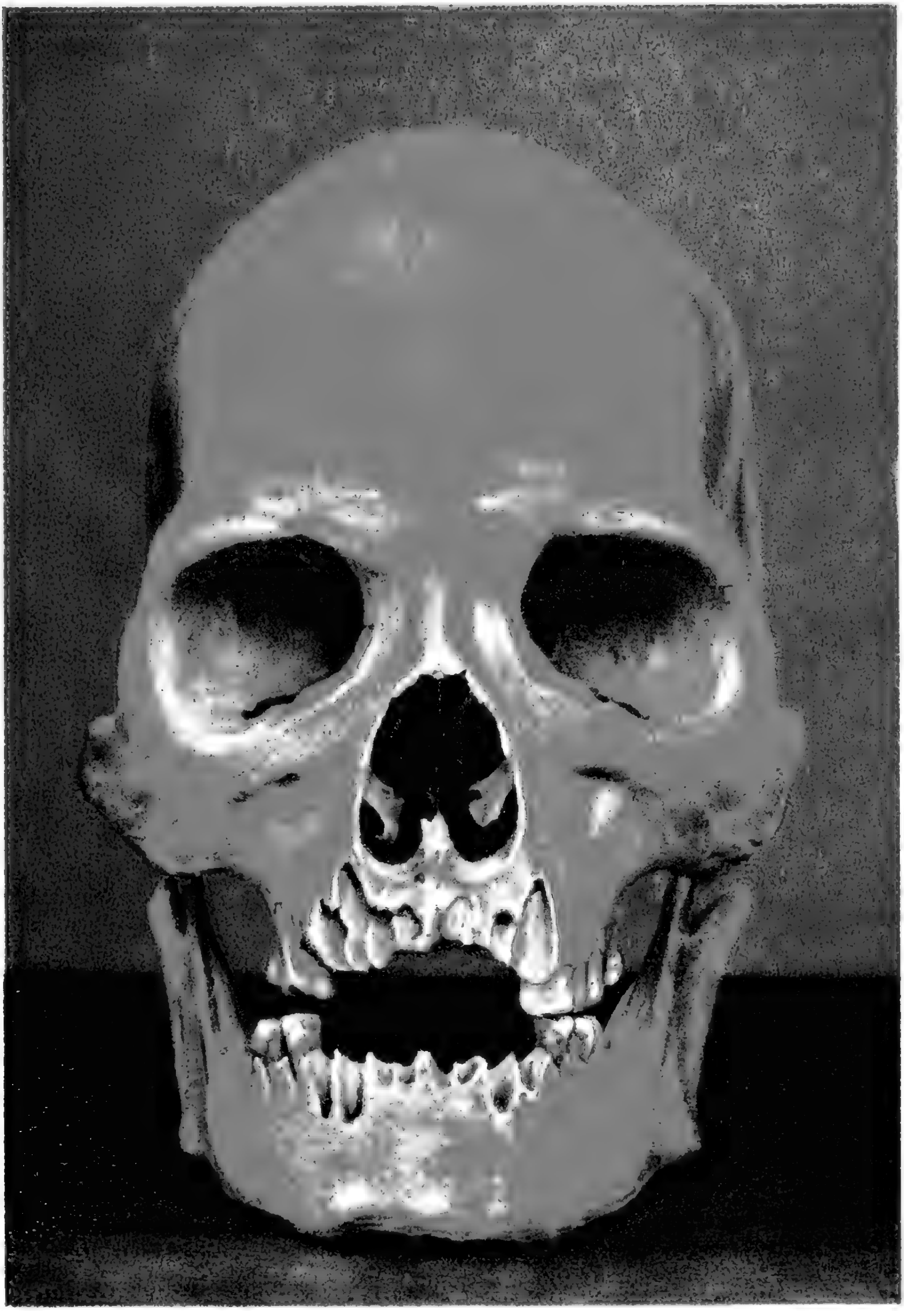

MALE SKULL, PAINTED RED, FROM LA PAZ, LOWER CALIFORNIA.

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SLING CONTRIVANCES FOR PROJECTILE WEAPONS.[a]

By F. Krause,
Leipzig.

There is already a rich, though scattered, literature on the subject of sling contrivances for missile weapons, but it is made up mostly of travelers' notes, mentioning these contrivances in certain localities, although there are also some comprehensive works treating them according to type and distribution. A general treatise, however, is still needed from which may be obtained a view of their distribution and varieties throughout the world.

The missiles are projectiles driven by the lever power of the arm in contradistinction to those like the ax, hammer, sword, knife, and lance, which depend upon the thrusting power of the arm and, with few exceptions, are intended merely for operation in the immediate vicinity. The most primitive projectiles were the stones and clubs and from the beginning the purpose has been to improve these missiles by giving them greater power of flight and surety of aim. This has been attained by lengthening the arm artificially and strengthening the lever power, from which great distance resulted. This was attained for the stone by means of the sling, and the club was made more efficacious by changing the form, as with the throwing clubs of the South Africans, the Fijians, and others; in the sickle-shaped missiles, so that they became formidable as a projectile; in the boomerangs of the Australians, or in the sharpened, thinner shafts for arrow or spear. The arrow, in its turn, could be sent afar through the principle of elasticity in the bow, an instrument encountered in all parts of the world, and which has further developed into arbalests and to firearms. Sling contrivances for the spear are found in certain parts of the world depending upon either the lengthening of the arm, upon lever power, or that which serves to give the spear a revolution upon its axis. These contrivances were formerly quite widely dispersed, but are now to be found only in certain widely separated localities. They are divided into two classes: (1) Spear slings,

[a] Condensed translation of "Schleudervorrichtungen für Wurfwaffen" in Internationales Archiv für Ethnographie, Leiden, Band XV, Heft IV, 1902. Colored maps accompany the original work.

usually called "throwing sticks," a misleading term, since it conveys a false meaning, as though these shafts were themselves thrown, while they merely serve as a help in throwing; and (2) throwing nooses and throwing thongs.

The spear sling is spread over four distinct areas: (1) Australia and, partially, Melanesia and Micronesia; (2) among certain northeastern Asiatics, as well as among the American and Greenland Eskimos; (3) Central America and equatorial South America, and (4) France during the reindeer epoch.

The throwing noose is found in (1) New Caledonia, New Hebrides, and New Zealand; (2) Hawaii; (3) Togo, India, China (?); (4) among the Romans, Greeks, Celts, Cythians, and other barbarians.

I. Spear Slings.

The spear sling is a piece of wood formed either flat, like a board, or in the shape of a rod; it is held in the right hand and attached at the foot of the spear. In throwing, the right arm, stretched backward and holding the apparatus, is thrust forward with full force; at the same time the spear is released. The spear sling thus lengthens the arm of the thrower and serves as a lever to thrust the lance forward after it has flown beyond the reach of the hand.[a]

According to the methods by which the sling stick is fastened to the butt of the spear, three kinds are distinguished by v. Luschan: (1) "male;" (2) "female," and (3) "mixed" (Zwitterhaften).

The male spear slings have a hook pointing toward the front, or grip at the upper end, and the spear has a small cavity or groove in the butt end into which the sling hook catches. The spear thus has a support until thrown off, and at the same time can easily release itself from the stick. In using, the native deftly catches the hook of this sling into the cavity at the butt of the spear, so that the instrument lies parallel to the underside of the shaft, while the outstretched left hand grasps the spear nearer the point, the fingers upward.[b] When the spear is to be thrown, "the (right) hand grasps the sling stick as well as the weapon. Both are then turned backward as far as the arm can reach, and the spear thrown forward with all the might."[c] One foot is generally thrust backward in

[a] Lauterer: Australia and Tasmania, p. 272.

The principle which v. Luschan advances (Das Wurfholz in Neu-Holland und Mikronesien) is not entirely correct. He compares the throwing motion with that of slinging an apple from a stick. But in this operation almost a quarter circle is described by the arm and stick, with the apple as center; about the same motion is therefore made as with the sling for stones. With the spear sling the same motion takes place as in ordinary spear throwing, except that the right hand does not itself hold the spear, but its continuation, the stick.

[b] Klemm: Werkzeuge und Waffen, p. 31 et seq.

[c] Lumholtz: Unter Menschenfressern, 1, 122 et seq.

throwing,[a] the discharge, therefore, occurring by the forward thrust of the sling-lengthened arm. This male spear sling occurs in different forms in Australia and in South America.

The female spear sling is provided with a groove along the upper side, which terminates in a cavity near the outer end. Into this groove the spear is laid lengthwise, and either its somewhat tapering end or hook set thereon is inserted into the cavity. (See the second variety of Greenland spear slings.) The spear lies firmly upon the shaft and easily releases itself from the cavity. The use is, in general, the same as the male spear slings. This class, with various modifications, is dispersed throughout Melanesia (especially in New Guinea), Micronesia, and Greenland.

Mixed spear slings are intermediate between the other two kinds. In these, at the end of the grooves on the upper side, a hook whittled from the shaft or inserted independently protrudes horizontally, or forward somewhat obliquely. On this the hollowed end in the butt of the spear is hooked. Its use is the same as in the other kinds. This class has the widest dispersion, being found among the northeastern Asiatics, American Eskimos, in southern North America, in Central America, and one variety in South America; also very probably in France. The spear slings of the Greenland Eskimos are somewhat analogous in construction and use.

The grips of the spear slings are greatly varied, in many classes no special grip being present; the shaft is grasped at the smoothed end (Australian). With others, on the contrary, care is taken that the hand may have a firm hold, and that the grip may not slip out of it easily. For this purpose the shaft at that point is made either rough by indentations or notches (Australian), wrapped with hair (Australian), or covered with rosin, in which a shell or stone is often stuck, to make a firm grip easy; a hole is made, in which the forefinger is inserted (Eskimo); one or more pegs project from the border, against which the index and other fingers rest (Eskimo, South American); or, finally, a grip is set on, in which again finger holes occur (Eskimo, Central and South American).

The operation of the spear sling is very important, as with it one should be able to send the implement three or four times as far as with the bare hands. The natives of Australia, for instance, hit quite accurately at 40 paces;[b] at 10 paces their spears still bear destruction to the victim;[c] and an Englishman saw a native of Port Jackson (Sidney) aiming the spear sling at a mark 276 feet away.[b] While spears can be thrown 50 to 75 feet with the bare hand, from

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[a] Klemm: Unter Menschenfressern.

[b] Klemm: Werkz. und Waffen. p. 31 et seq.

[c] Lauterer: Austral. u. Tasmania, p. 272 et seq.

the spear sling they easily reach 200 to 300 feet.[a] Indeed, according to Clutterbuck,[b] the Australians are said to have made even 150 yards with the spear sling. Whether these last statements are entirely accurate we can not decide, but one constantly sees references to great distances attained by aid of the spear sling.

LOCALITIES AND TYPES.

We now turn from this general view to the localities where the spear sling is used, to familiarize ourselves with the types there occurring.

The region in which spear slings are most frequent, even at the present day, is Australia. The principal weapon of the Australians is the spear, 3 to 4 meters in length, and all Australian spears except those used in catching fish are thrown by means of a sling, called "wommera,"[c] which is used both in war and in the chase. It was at one time distributed throughout Australia, but, being supplanted more and more by firearms, slings are now limited to West Australia from the north and the territory beyond New South Wales and Victoria.

The male type only is found in Australia, and may be divided into two large groups. In the first the hook and shaft are in one piece, while in the second group the hook is a separate piece (bone, tooth, wax), often of different material than that of the shaft, fastened on by winding with reed and thread and smeared with wax.

This first group occurs only in Melbourne and vicinity. The grip of the shaft is rounded, often thickened by means of wax, sometimes roughened by means of incisions to prevent the hand from slipping during slinging. The shaft broadens toward the center and suddenly tapers to a point at the outer end. The under side from the center out is slanted or rounded toward both edges, the upper side slightly hollowed. Very broad and very narrow forms occur, as well as round, between which are all intermediate degrees. They are often carved, especially on the back, with all sorts of figures and with the line ornamentation so general in Australia (pl. I, figs. 1 and 2).

Those of the second group, with the hook composed of wood, bone, tooth, or wax set into the outer end of the handle, are subdivided into two types, with numerous subdivisions. Type I comprises broader or narrower blades, or those slightly hollowed on the under side, while Type II is of round shafts. Type I again falls into two subdivisions: (*a*) The spear sling is more or less broad, therefore leaf-shaped; the hook is fastened at the upper end upon one side; (*b*)

[a] Wallace: Australasia, 3d ed., p. 124 et seq.

[b] Waitz: Anthropol. der Naturvölker, VI, p. 472 et seq.

[c] Ratzel: Völkerkunde, II ed., p. 43 et seq.

the slings are likewise rather broad, the hook not fastened to the flat surface but to the edge of the shaft. The spear slings with the hook upon the face are found from King Georges Sound to Geography Bay,[a] in the great west Australian desert, in Nullagine, on the tableland, and by the Sherlock River.[b] The second kind is therefore restricted to West Australia. It is a thin, extremely broad, long-oval board, often hollow on the upper side and slightly curved upon the lower, the small wooden hook is set upon the face, so that great wind resistance is overcome during use; why the shaft is so wide is not known; at least, no advantage is to be derived from the breadth. The grip is composed of a lump of gum, applied either symmetrically or slightly sidewise, from which protrudes a piece of shell or stone, the latter serving for a firmer grip, sharpening the spear points, and generally as a cutting instrument, since it has an edge.[c] This type of spear sling is quite abundant (pl. I, fig. 3). The type found among the Nannines (West Australia)[d] is similar, it is a not very broad, parallel-sided, flat stick, about 1.20 meters long, tapering at both ends. The wooden hook is attached above on the face, a piece of gum is applied for a grip, in which is a piece of shell or stone (pl. I, fig. 4). This leads to the type used from Beagle Bay northward as far as Port Darwin,[e] at Carpenter Gulf, and in the northern territory of South Australia;[f] perhaps even farther inland to the Eiry Lake.[e] The shaft is of nearly the same form as the preceding, except that it is not parallel-sided, but tapers toward the outer end. The grip is clearly defined and allows a firm grasp. The hook being bound to the shaft with cords and gum, the entire shaft is then covered with a reddish earth. Decorative figures are often carved upon the sides (pl. I, fig. 5).

The type found from Port Darwin to Port Essington and on Melville Island is quite as flat, narrow, and pointed,[g] it differs from the foregoing in that the shafts are bent and very elastic. The handle consists of a pear-shaped piece of gum. That part of the shaft next the grip is ornamented in lines. What advantage these particular shafts present is not known, as they are elastic, they permit a bow thrust, and at all events, they make throwing a greater distance possible. They are quite rare (pl. I, fig. 6). A class which but partly

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[a] According to v. Luschan: Das Wurfholz in Neu-Holland und Oceanien, p. 138.

[b] According to statements found with the shafts in the Leipzic Museum of Ethnography (Grassi Museum).

[c] Schurtz: Urgeschichte der Kultur, p. 339.

[d] Four examples of this type are in the Leipziger Museum für Völkerkunde.

[e] After v. Luschan: Das Wurfholz, p. 140.

[f] According to statements on the shafts in the Leipzic Museum.

[g] After King. See Waitz: Anthropologie der Naturvölker, VI, p. 742 et seq.

belongs to this group is used on the Murray River. The grip is very long and cylindrical; the shaft then swells to a broad central portion, arched underneath and flat on top, which graduates toward the outer end and terminates into a rounded [illegible]aff, where a kangaroo tooth is fastened. The grip is made rough or [illegible] opossum fur applied to prevent the slipping of the fingers. This k[illegible] forms the transition to the second type, the rounded stick (pl 1, fi[illegible]).

The second group of the first type is of bro[illegible]r or narrower shafts, to which the hook is attached, not upon the [illegible]e, but upon the edge. They are found particularly upon the Cape York Peninsula and in northern Queenland; perhaps also in New South Wales. Certain variations again appear within this type: On one kind, usual on Cape York Peninsula, two long oval shells are attached slantingly above. Whether these serve merely as a grip for the hand or some further advantage is to be attained through them is not known (pl. 1, fig. 8).

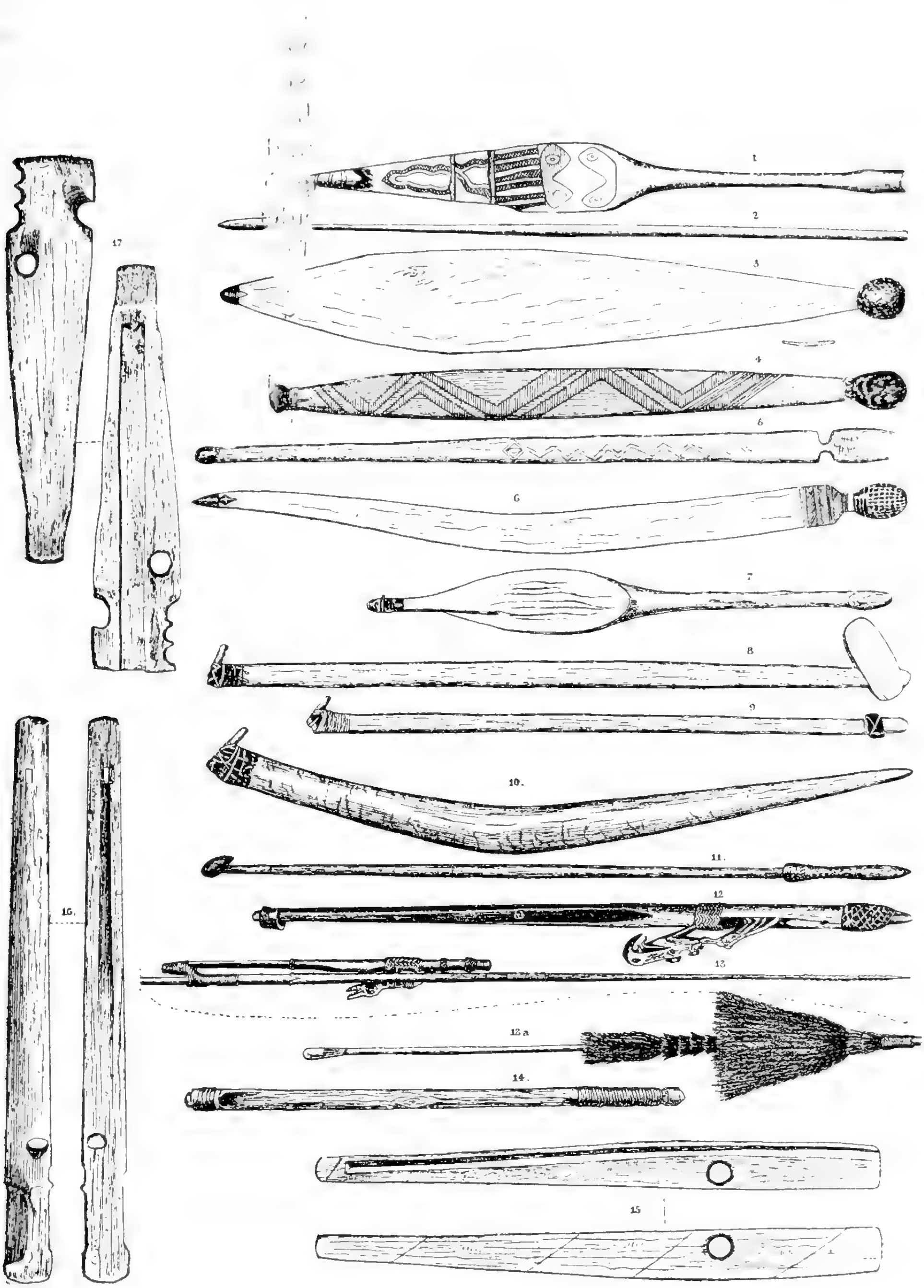
Another kind, also from Cape York Peninsula, is substantially narrower and shorter and does not have the shell, but a quite smooth grip, which, however, has distinct lashings. It may be that the shell has been lost; in that event both these types would be in a single group (pl. 1, fig. 9). Lastly, a third type similar to the boomerang occurs in northern Queensland. As the tooth protrudes beyond the edge, it is quite probable that this shaft was also a boomerang, and is a doubly useful weapon (pl. 1, fig. 10.) Only with these three weapons is it possible to swing the stick in a circle, according to v. Luschan's principle. But at all events, as the hook is on the edge, these three types serve to develop the utmost slinging force of the shaft, for by it the wind resistance is easily overcome and distance and accuracy substantially increased. These are, perhaps, the most perfect spear slings in Australia. One reported by Klemm[a] may also belong here, as it occurs at Port Jackson and in the vicinity of Sydney. He merely says that a native attained a distance of 276 feet with the spear sling. He characterizes the implements generally as 5 feet long, with a small peg or hook at the outer end and a shell at the opposite for ornament, which serves as a grip.

The second type of the second group presents long, rounded shafts, and is usual in northeastern Australia, especially in the northern territory. These are plain, rounded shafts about 1.20 meters long, tapering slightly toward the outer end. The grip is thickened by means of concentric layers of gum[b] or wound with cords twisted from human hair, showing a large tuft at the end,[c] and the hook is a

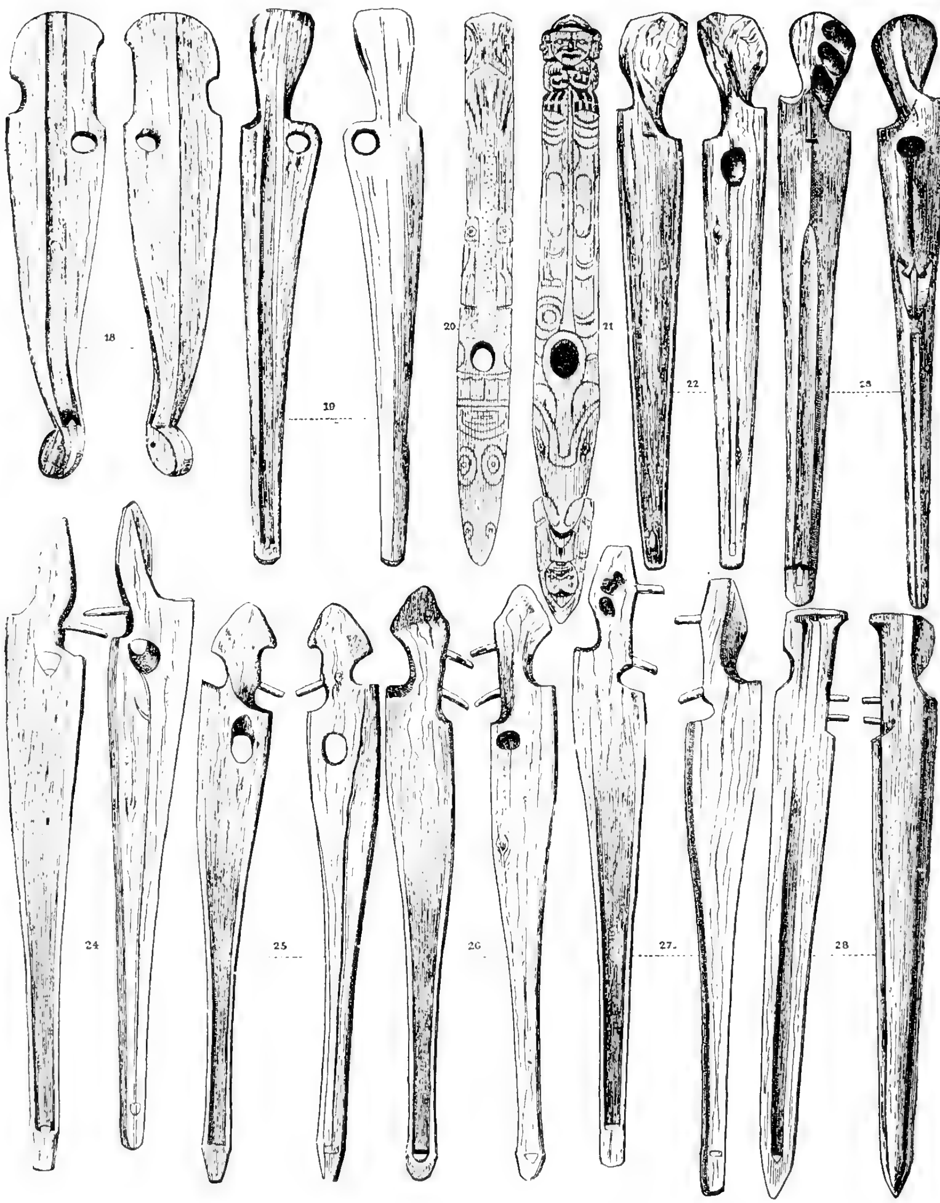
[a] Klemm: Werkzeug und Waffen, p. 31 et seq.

[b] According to v. Luschan; Das Wudfholz, pp. 142–143.

[c] Schmeltz: Intern. Arch., 1, p. 136 et seq.; Uhle: Intern. Arch., I, p. 196.



SLINGS FOR HURLING WEAPONS.



SLINGS FOR HURLING WEAPONS.

large wooden tooth or a lump of gum which ends in a sharp point (pl. I, fig. 11).

Luschan[a] gives ten or twelve sharply defined types of Australian spear slings, which are characteristic of the localities where found. These types have been discarded here, and a new division made as follows: The chief characteristic on the spear sling is the hook. According to its various modes of attachment, spear slings are divided into those having hook and shaft in one piece, and those in which the hook is attached independently. The latter, according to shape, have broad shafts, board-shaped, or round shafts, with two smaller groups of those with hook on the face and those with hook on the edge.

In the greater or less breadth of the shafts, in the variety of grips, in the straight or twisted forms of shafts, there are not such varieties for characterizing a main division as in the different fastenings of the hook, the principal piece on the male spear sling. All these slight differences must be regarded as local modifications of the present main type.

The second area in which spear slings appear is northeast from Australia, in Melanesia, or, rather New Guinea and Micronesia, in which area spear slings are chiefly used as weapons of war,[b] whether also of the chase there are no accounts. It probably earlier spread through Melanesia and Micronesia, but is known only from New Guinea, the Fiji Islands, the Carolines, Pelew, and Marianas. According to type, only female spear slings occur here.

We can further distinguish two groups of spear slings—those with a piece and those without a piece attached. The former occurs in New Guinea only, and the spear sling is here on the German north coast as far as Astrolabe Bay, covering Empress Augusta River,[c] Cape della Torre,[d] Venus Hook,[e] Hansa Inlet,[f] Hatzfeldhafen,[f] Cape Gourdon,[f] Hammaker River,[g] Astrolabe Bay,[f] where they are very numerous and always beautifully worked.[h] This spear sling is made of a shaft of bamboo 60 to 80 centimeters long, cut off so that one end (the upper) terminates at a knot. About two-fifths of its length (measured from grip) the shaft is split off in such manner that at one end one-fourth and at the other three-fourths of its thickness is cut

[a] v. Luschan: Das Wurfholz in Neu-Holland und Oceanien.

[b] Keate: Pelew Islands (1789), p. 414 et seq. Schmeltz: Intern. Arch., I, p. 67.

[c] Uhle: Intern. Arch., I, p. 196.

[d] Schmeltz: Intern. Arch., I, p. 136. Note 7.

[e] Tappenbeck: Deutsch New Guinea, p. 73.

[f] According to statements on specimens in the Leipzig Museum.

[g] Finsch: Erfahrungen und Belegstücke aus der Südsee, p. 212.

[h] Krieger: Neu Guinea, p. 43 et seq.

away. The knot at the end is retained and shows a small excavation. The spear belonging to this, 2.50 to 3 meters long, has in the middle, near the center of gravity, a short hook bent backward, artistically fastened to the shaft with a rattan or bast binding. In use, the spear is laid lengthwise in the furrow of the sling, but in such manner that the little wooden hook catches into the hollow at the knot.[a] The spear thus has a support in throwing outward and releasing, but still does not lie firmly enough to enable it to hit a mark. To achieve that, and to assure a certain direction of flight, an attached piece is placed between the beginning of the groove and the grip, always lying in a groove by itself. Beginning at the grip, it rises at a slant of some 10 centimeters above the beginning of the groove and is securely bound to the shaft with string bands. It does not lie on a line with the spear groove, but alongside and parallel. It is whittled from wood and ornamented with great care, the favorite forms carved being those of animals, kangaroo, rhinoceros birds, and crocodiles frequently appearing as attached pieces, often completely conventionalized so that their meaning is obscured (pl. I, fig. 12).

As already indicated, the purpose is to give the spear a firm support to hinder its gliding off. In use, therefore, the hook is inserted into the cavity, the spear laid into the groove with the right side leaning against the attached piece, where it is tightly pressed with the thumb, the fingers clasping the grip, the attached piece here taking the place, so to speak, of fingers (v. Luschan). The grip is simply the smooth reed, seldom ornamented, but often covered with plaited work, so that the hand has a firm hold, while at the knot are all kinds of decorations, notched carvings and plaited bands, which are at the same time to hold the reed from splitting. The motion in slinging off is the same as with the Australian spear slings (pl. I, figs. 13 and 13a).

All other spear slings in Melanesia and Micronesia are without attached piece. They have probably died out here entirely, for examples are little known. There are many reports of their appearance in this district, but the fact is announced without giving precise description of the stick and its weapon. Waitz mentions spear slings of the Fiji Islands. (Anthropologie der Naturvölker, VI, p. 597 et seq.) The weapons are here beautifully worked. They are

[a] Parkinson: Die Berlin-Hafen-Sektion; Intern. Archiv., XIII, p. 29. Finsch: Ethnologische Erfahrungen und Belegstücke aus der Südsee; Wien, 1893, p. 212, confirmed likewise by Doctor Liese in a verbal contribution to Doctor Weule in Leipzig. Doctor Liese was in New Guinea for a long time and there saw this practice, and upon his return brought several examples which are now in the museum at Leipzig. Doctor Weule demonstrated with these. Compare therewith v. Luschan: Das Wurfholz, p. 148, whose opinion, accordingly, is incorrect.

also mentioned from the Caroline Islands, the Philippines, New Guinea, and Pelew Island.

In type these shafts were similar to those of New Guinea, even to the piece attached and the finer execution (pl. 1, fig. 14). The spears there have no spine set on, as those from New Guinea; it is therefore presumed that the sharp butts of the spears are stuck into the hollow at the outer end of the spear sling, and are held securely by the first, second, and fourth fingers of the right hand. The practice is, therefore, nearly the same as in Australian spear slings. An attached piece is, of course, superfluous. Report is made of another use of spear slings in the Pelew Islands; the elastic bamboo spear is set with its point in the groove of the shaft, the left hand holds the spear toward the outer end and inclines it more or less according to the distance sought. When the hand is removed the spear flies and usually falls perpendicularly upon its target.[a] Reports of Chamiso from Yap will probably be similar, that the spear was shot from the bow with the aid of a trough-shaped piece of bamboo.

The third area in which spear slings are found, having much variety in shaft and quite extensive use in hunting on the water, even though it is being supplanted by firearms, is the polar regions.[b] They are used there among the Giliaks (Amur district and Saghalin), among certain northeast Asiatic races, upon the Aleutian Islands, on the shores of Alaska, on the north coast of America, in Labrador, Greenland, and among the Eskimos generally. The Greenlander, whose artistic spear slings will be considered further on, is here omitted. According to the provision for the forefinger,[c] three groups are distinguished: (1) A hole for the forefinger is cut on the side of the shaft to the right from the spear groove; (2) the pocket or cavity for forefinger is placed on the central line of the under side and, if it goes through, terminates in the spear groove; and (3) a notch for the forefinger is cut to the right of the grip, from behind which protrudes a peg. We find the first group in Labrador, Baffinsland, along the entire northern coast of North America, in Alaska, on the Fox and Aleutian islands, as among the Giliaks, and certain northeast Asiatics. It is usually a broad strip of wood, tapering more or less to a point at the outer end. A groove for the spear is made on the flat upper side, from the end of which projects a small bone hook (this is not fastened with gum and bindings, as in the case

[a] Keate, Pelew Islands (1789), p. 414 et seq.; 188 et seq.

[b] Mason, U. S. National Museum Rep., 1884, pp. 279–289, 17 pls.

[c] The plan has been arranged according to the provisions for the forefinger, as this is the most distinguishing characteristic of these north-country sling sticks. This division makes possible a simple grouping of the different kinds, and a clear view of their distribution in these areas, both geographically and ethnographically.

of the Australian sticks, but is inserted in the shaft). The groove deepens as it approaches the hook; toward the opposite end it becomes shallower and terminates in the handle. To the right of this groove, at the more or less distinctly defined grip, is a hole through which the forefinger is placed during use, making impossible the slipping of the board. The grip either is quite smooth on the edges or has notches for the fingers. The spear, thick, heavy, and harpoonlike, has a cavity at its square end into which the hook of the spear sling fits when in use, while the spear itself lies in the groove. The left hand holds the spear toward the point, otherwise the mode of shooting is similar to that of the Australian spear slings. Slight modifications of this variety, all pertaining to the grip, are noted in different localities in the polar regions.[a]

Why are such distinct handles encountered here in the north? The answer is easy. Because of the small diameter of the forefinger hole it is not possible to use gloves; the natives are, therefore, forced to take hold of the spear slings with the bare hand. Even then, because of the strong jerk in throwing off, the last-named tend to glide out of the hand. How much more will it not be the case when cold-benumbed hands try to hold the smooth shaft? It is necessary, therefore, to attain the firmest possible grasp, which, as we have seen, has been done with these artistic grips. The most perfect in this regard is the shaft of the Mahlemut, in which all the good qualities are included—distinct handle, thumb groove, forefinger pocket on under side, finger grooves on the side, with peg and finger-tip cavity, shaft groove, and end hook. As to our three principal kinds, the first is from Baffinsland and Labrador onward over the entire north coast of North America as far as northeast Asia, and returns to America through the Giliaks, Aleuts, Unalaskans, and Kadiak islanders as far as Prince William Sound. It is important to notice that this variety is to be found among the northeast Asiatics, Giliaks, and Aleuts, since this might help to prove the relationship of these isolated peoples to the Eskimos in a broader sense, in addition to other similarities.

We now come to the spear slings of Greenland. Three varieties are also used here, which are attached to the spear by an entirely new method. The spear slings lying before me are genuine works of art, wrought probably with iron tools and ornamented with inlayings of bone. They were finished off upon the order of a Greenland missionary who was having a complete Kajak outfit made for

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[a] The author describes rather minutely a number of varieties in the form of the shaft and the grip, which are omitted in this translation. They are illustrated in pl. I, figs. 15–17, pl. II, figs. 18–28 (also see Mason, Rep. U.S.N.M., 1884).—EDITOR.

himself; but, having no use for it, it was transferred, still new, to the possession of the Leipzic Museum für Völkerkunde, together with three spear slings and all appurtenances. The first variety is a shaft 43 centimeters in length, tapering slightly toward the outer end about 5 to 8 centimeters broad, called "Norsók" ("Vogelwurfbrett"), according to Virchow, which is used for throwing in a straight line, and is also used in this manner in Labrador (pl. III, figs. 30 to 30e). The upper side is flat; the under slanted off both ways from a central line. In the middle of the upper side a groove shallows from the start and stops short before reaching the outer end of the stick, so that a small, smooth space is left. Upon this a tapering bone hook is attached, leaning toward the front and projecting over the groove. On both sides of the grip are thin bone pieces somewhat tapering, which secure a firmer grip. No ornamentation is present in this kind. A very ingenious harpoon is thrown with this, having a quite strong, round shaft, 1.15 meters long. At the butt end a bone plate is set, which is so hollowed out that the point of the spear-sling hook fits exactly into it. The comparatively long iron head with harpoon blade is so fastened that when the toggle strikes it remains in the animal and is still connected with the shaft by means of a leather line. The shaft now turns downward and takes a perpendicular position in the water and a bladder attached at the other end easily holds the shaft upon the surface of the water and shows the hunter the position of the animal.[a] The method of throwing is the same as with Australian sticks.

The second variety is even more ingenious. It is female, and the groove extends from front to back, the shape and the handle being otherwise the same as with the first variety. Two holes in the groove are to be noted, one occurring about the middle of the grip, the other in a bone set on at the end of the groove fitting into it. The hole is not perpendicular, but slants backward. The shaft is decorated with five carved walrus-ivory pieces inserted in each side of the edge (pl. III, figs. 31 *a* to *e*). The accompanying harpoon is 2 meters long, with solid iron point inserted into a piece of bone. The thick shaft, at 20 centimeters beyond the center of gravity, has two bone pegs corresponding to the holes in the spear slings, and set backward to fit into them. In use the spear is laid in the groove of the spear sling, the pegs fitted into their holes. The shaft then still projects 50 centimeters backward beyond the board. The spear sling is not applied at the end, but quite in the center of the spear (as with those from New Guinea). In slinging, according to Virchow,[b] the thrower gives a slight push upward, so that the first peg rises from the shaft;

[a] Klemm: Werkz. und Waffen, p. 33 et seq.

[b] Virchow: Verhandlungen der Berliner Anthropol. Gesellschaft, 1880, p. 268 et seq.

the second hook, as it is placed slantingly backward, easily releases itself from the shaft, and serves to help it in swinging off. A strongly curved thrust is attained after the first push in swinging off. This implement is used in hunting aquatic animals, for which a curved thrust from the kaiak is necessary.

The third variety is most interesting. Its shaft is generally of the same form as the foregoing, except that it tapers suddenly at the outer end to the half of its width. The grip is about the same as the preceding, the reverse, slanting toward each side, is not decorated. The shallow groove runs from front to back. Eight centimeters distant from the inner end, in the center of the groove, is a hole, which narrows toward the bottom. In the groove at the upper end a narrow bone about 6 centimeters long is inserted, which bends upward and forward to a hook extending from the end of the weapon (pl. III, figs. 32 *a* to *e*). The harpoon accompanying it, called "erneinek" (Klemm), is 1.60 meters long, somewhat thicker front and back than in the center, and leveled. The bone point is bound fast to the shaft, on the butt end is a bone plate with a small hollow, on both sides of this a long, flat, broad piece of bone is attached, formed like a shuttle (Klemm), which extends about 12 centimeters over the end. Both these plates are very ingeniously fastened by means of small bone rivets. Thirty-seven to forty-two centimeters from the back end a bone hook is struck through the shaft at right angles, so that the hook nearest that end is on a level with the flat surface of both bone plates. In use the hook of the spear sling grips into the cavity of the end plate between the two prolonged flat bones. The other hook, 37 centimeters distant, grips into the hole in the shaft, which is supported by the left hand. Again an upward push is given from the front, so that the spear releases itself from the board. The back hook then gives the proper swing and direction, and thus results a curved thrust. Both the side pieces of bone at the back end serve, according to Klemm, to make the aim straighter and surer. They therefore serve the same purpose as the feathers at the end of the arrow. At the second hook an 8-fathom-long leather line (Klemm) is fastened by means of a bone ring. So it is seen how the Eskimos, "with much intelligence, with simple appliances, have provided themselves with an implement for the main purpose of their existence, the hunt, which allows them to take their prey at considerable distance from their kaiaks and with the greatest safety." (Virchow.)

The last area of distribution of the spear sling is Central and South America. It was used both in the chase and in war. The spear sling was in use, probably till the end of the conquest (1530), in Utah,[a] Colorado, California, Florida, Mexico, Yucatan, on the

[a] George H. Pepper: Internat. Cong. of Americanists, N. Y., 1902, 107–130.

Greater Antilles and Lucayas, in Central America (in the east and south) in Columbia, Ecuador, Peru, and in the Amazon River district, east Peru, and north Brazil. It is still in use in Michoacan, on Lake Patzcuaro, and in Brazil among the tribes of the upper Xingu and Araguaya. There are three types—one androgynous and two male. The androgynous form is the old Mexican atlatl. The shaft is thin and not very strong. For a grip it is hollowed out on the edges, and a leather thong forms a loop on either side for the second and third fingers, or a piece of shell is attached to the back; or a piece cut from shell [a] is placed on each side of the handle; or braided cords [b] take the place of the thong; or, in rude types, a crosspiece only is attached, which projects to right and left. Finally, there is a groove in the center, or often one at both sides of the shaft. San Marcos, Fla.,[c] Santa Barbara, Cal.[d] The grip is like one from Greenland (see pl. III, fig. 33). On the front a furrow diminishes toward the outer end, where a peg protrudes. In the class made of rings of shell a piece of hide is attached,[e] by the aid of which the third and fourth fingers press against the board from beneath. The upper end was often decorated with feathers, hair tufts, or narrow thongs. Sometimes a transparent quartz pebble was attached (according to Starr, 5) as a luck stone (see pl. IV, fig. 34). In use the second and third fingers hook into their rings, the spear is laid into the groove, and the cavity at the end rests against the peg. The first, fourth, and fifth fingers encircling the shaft hold the spear securely upon the sling. This form was still in use about the time of the discovery of America. In the descriptions and illustrations of Spanish historians of the conquest they are incorrectly drawn and explained.[f] It was used in war, but oftener in the chase and in fishing.[g] It appears in ancient calendars and picture writings, especially associated with the sun god Tonatiuh or Xiuhpilli, the fire god Xiuhtecutli, and of Tezcatlipoca,[h] as seen in the works of Durian, Torquemada, Ramusio, Oviedo, Robledo, etc. It occurs singly upon sculptures and on the plaster casts in the Musée du Trocadero, from Olmec Uixtotin, on the Isthmus of Tehuantepec.[i] Examples are preserved from the cave

[a] Doctor Seler: Intern. Arch. III, p. 137–148; Stolpe: Intern. Arch. III, p. 234–238.

[b] Doctor Seler: Intern. Arch. III, p. 144; the same: Globus, 61, No. 7, p. 97.

[c] Mason: Intern. Arch. XI, p. 129, et seq.

[d] Dalton: Intern. Arch. X, p. 229, et seq.

[e] Starr: Intern. Arch. XI, p. 233; Doctor Seler: Intern. Arch. III, p. 144.

[f] Doctor Seler: Globus, 61, No. 7, p. 97 et seq.; Doctor Uhle, Mitth. der Wiener anthrop. Gesellschaft, XVII, 1889, pt. 2, pp. 107–144.

[g] Schuts: Urgeschichte der Kultur.

[h] Doctor Seler: Intern. Arch. III, p. 139.

[i] Doctor Seler: Globus, 61, No. 7, p. 97 et seq.

dwellings and tombs—for instance, from the mummy caves of the hacienda del Coyote, in Coahuila,[a] or from San Marco, Fla.,[b] Santa Barbara, Cal.,[c] Utah,[b] and southwestern Colorado, and besides the ordinary ones, several magnificent examples, certainly not intended for use, being richly ornamented with carvings, paintings, and gilding, and representing temple decorations, and probably dedicated to the rain goddess Tlaloc,[d] as they show her symbol. These beautiful examples come from Tlaxiaco, in Mixtec, in the street of a Pueblo toward Oaxaca.[e]

The same type still appears at this day in spear slings used in Michoacan on Lake Patzcuaro.[f] There is no account from ancient times that this type was in use in war, but it is still employed in hunting water fowl[g] on Lake Patzcuaro, the flat shores being covered with bamboo thickets in which thousands of ducks nest. The spears are about 2 to 3 meters long and have a three-pronged point. The spear sling from this area is flat on the upper side and half round on the lower, 60 centimeters long, with round grip, which broadens into a flat piece which has two holes for the third and fourth fingers. (Doctor Seler also mentioned[g] that the shafts from Patzcuaro Lake, of which Mason gives first notice, had ears cut from shells, tied on with cotton cord, one on each side, for the third and fourth fingers. According to these writers, the shafts are very similar to those of the ancient Mexicans). The shaft narrows outward and has a broad deep groove on the upper side, at the end of which a small hook is carved from the shaft. The grip is cut to fit the hand and terminates in a hook which serves to draw the spear out of the water (see pl. IV, figs. 35 and 36). This type was employed in Utah,[g] southwestern Colorado,[h] California,[i] Florida,[j] Mexico,[g i k l] especially in Coahuila,[k] in Yucatan among the Tutulxiu,[k] Isthmus of Tehuan-

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[a] Doctor Seler: Globus, 61, No. 7, p. 97 et seq.

[b] Mason: Intern. Arch. XI, 19; Starr, ibid., p. 233 et seq.

[c] Dalton: Intern. Arch. X, p. 225 et seq.

[d] Herman Strebel: Intern. Arch. IV, p. 225 et seq.; compare also Doctor Seler: Intern. Arch. III, pp. 137–148, who considers that they are temple pieces dedicated to the rain god.

[e] Doctor Seler: Intern. Arch. III, p. 137 et seq.

[f] Starr: Arch. XI, p. 233; also Globus, 78, p. 207; and Indians of southern Mexico, pl. 21.

[g] Starr: Arch. XI, p. 233 et seq.; and Pepper: Cong. of Americanists, 1902, p. 107 et seq.

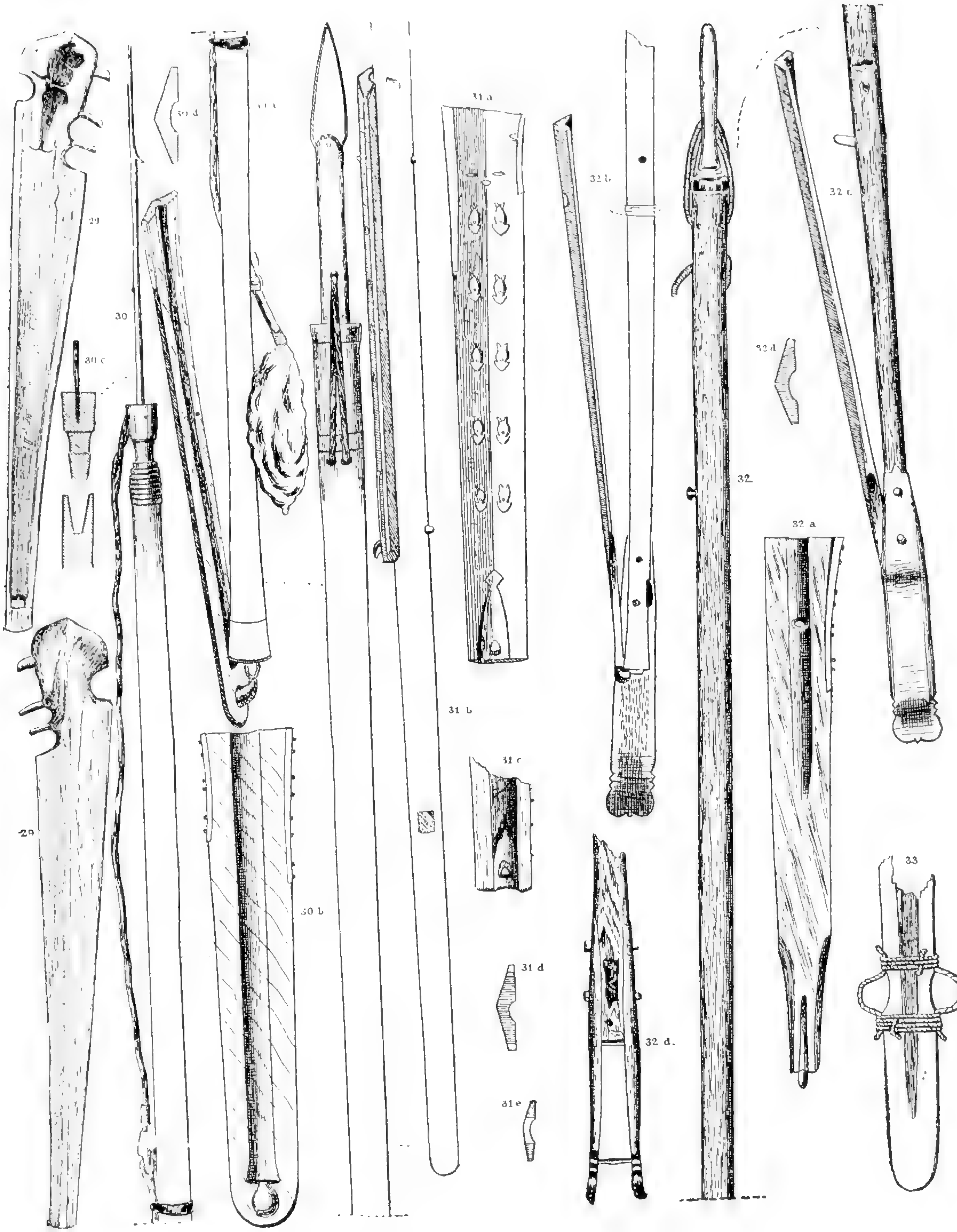
[h] Mason: Arch. XI, p. 129 et seq.

[i] Dalton: Arch. X, p. 225 et seq.

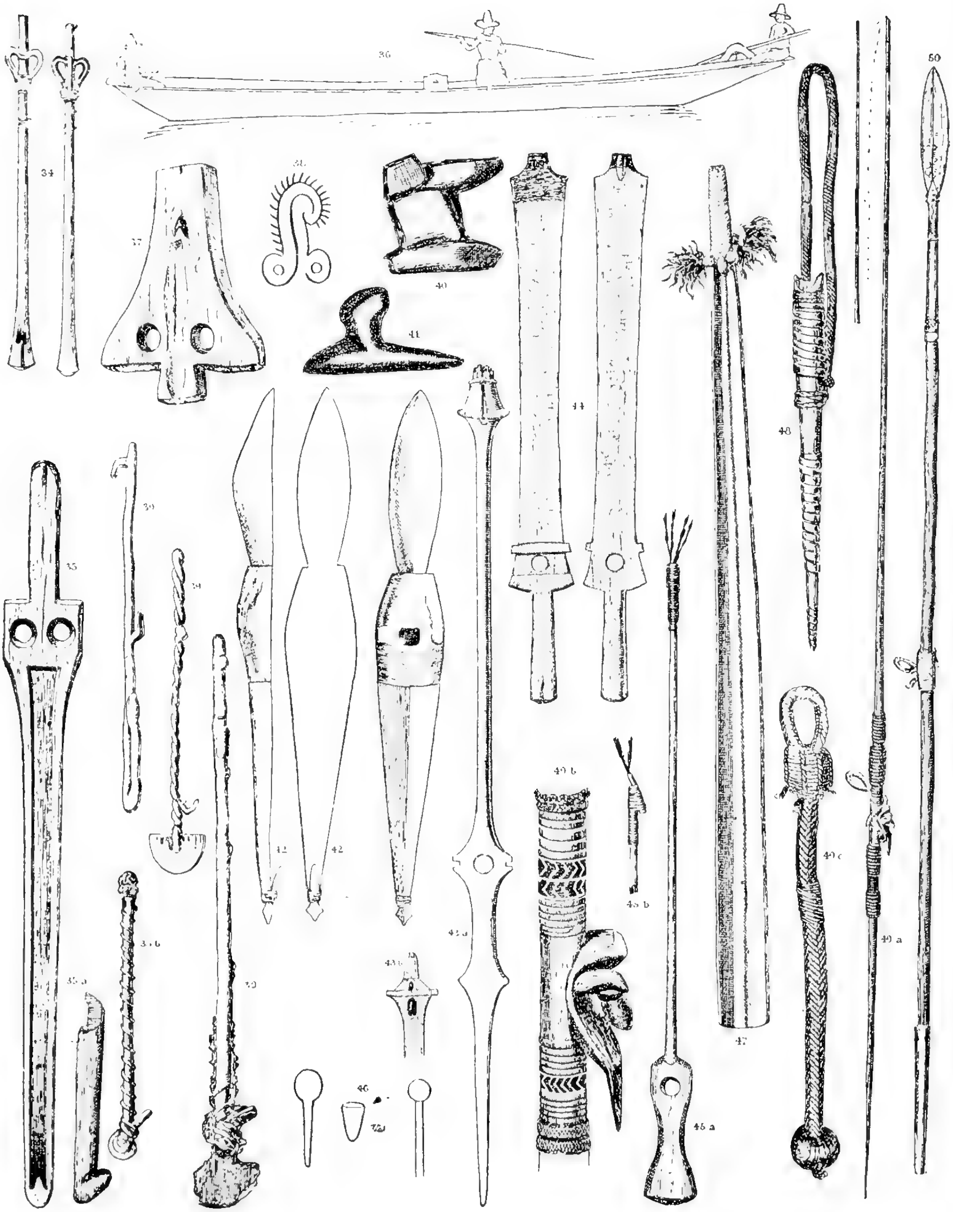
[j] From the Key dwellings on the Gulf coast and from San Marco in Florida; Mason: Intern. Arch. XI, 19. After Dalton: Proc. Amer. Philos. Soc. Phila., 1897, vol. 35, Pl. XXXV, f. 4.

[k] Mummy Cave of the Hacienda del Coyote; Doctor Seler: Globus, 61, p. 97.

[l] Uhle: Mitth. Wiener Anthrop. Gesellsch., 1887, No. XVII, part 2, pp. 107–114.



SLINGS FOR HURLING WEAPONS.



SLINGS FOR HURLING WEAPONS.

tepec (Olmeca Uixtotin, from clay figures in the Musée du Trocadéro),[a] Palenque in Guatemala,[b] Panama,[c] Province of Cueva (after Oviedo[d]), in addition probably also on the Greater Antilles and Lucayas (Bahama Islands[e]).

According to Starr the spear sling is still in use on the inner angle of the Atlantic Gulf coast, in Tenanpulco, in Apulo, and at Tecohitla and Nanthla River. Another shaft is here to be mentioned which is probably the prototype of the Mexican. It is from Santa Barbara, Cal., and seems shorter than any other known[f] (see pl. IV, fig. 37). The shaft is broad and thick and about one and one-half times as long as wide. On the upper side, extending from the front, is a narrow groove which ends at two-thirds of the distance. At the outer end a sharp tooth bent forward protrudes. Two finger holes, one at each side of the groove, are bored through the shaft, as in the spear slings of Florida and Lake Patzcuaro. It is assumed that this is the original of the Mexican spear sling; for, first, the short length is proof that the evolution of the spear sling is here in its first stage; secondly, ancient illustrations of spear slings not much longer are to be seen in Doctor Seler: Intern. Arch., Volume III, page 139, figure 4 (see fig. 38), the Codex Mendoza; thirdly, Mrs. Nuttall mentions, as a weapon of war, a spar sling only 23 centimeters long.

The second type was in use in northwestern South America. In Colombia, among the Chibchas;[g] in Ecuador, among the Purahaes (according to Cieça) as in the vicinity of the Latacunga; beyond this, mainly on the highlands (Oviedo, Valesco), and Quito,[h] on the Riobamba,[i] as in Peru,[j] quite common. No spear sling now occurs there. All that we know of it is learned, either from descriptions and illustrations in Spanish writers, from facsimiles in gold (for example those of Chibcha in the Leipzig Museum), from pictures on pottery (Peru), or from a few examples still in existence (from Quito, in Rome; from Riobamba, discovered by Mr. Reiss). This type is entirely different and decidedly masculine. A rough stick

[a] Mummy Cave of the Hacienda del Coyote; Doctor Seler: Globus, 61, p. 97.

[b] Uhle: Mitth. Wiener Anthrop. Gesellsch., 1887, XVII, part 2, pp. 107 et seq.

[c] Waitz: Anthropol. der Naturvölker, IV, p. 349.

[d] Mummy Caves of the Hacienda del Coyote; Doctor Seler: Globus, 61, pp. 97 et seq.

[e] Waitz: Op. cit. IV, p. 322, according to Narraveta I, 21, 75, 219; Ovieda, III, 5.

[f] Dalton: Notes of an Ethnogr. Collection * * * Intern. Archiv., X, p. 225 et seq.

[g] Waitz: Anthropol. der Naturvölker, IV, p. 369; Guarantors: Oviedo, Simon Piedrahita.

[h] Stolpe: Intern. Archiv., III, p. 237.

[i] Uhle: Mitth. Wiener anthrop. Gesellschaft, No. XVII, 1887, pp. 107–114.

[j] Dalton: Intern. Archiv., X, pp. 225 et seq., from illustrations upon a vase from Peru, in possession of Mr. Read.

has close to the grip a hook of wood, stone (Chibcha), or bone (Quito), at an angle of 90 degrees. Near the upper end the shaft broadens into a small disk handle (see pl. IV, fig. 39); in using, the right hand grasps this disk, and the forefinger the side hook there found, the spear, as usual, being set against the upper hook. These are abundant in collections,[a] a number being in the Leipzig Museum, showing that at one time the spear sling was widely dispersed and much used (see pl. IV, fig. 40). The typical form of this hook is a small straight base with a fluke joined to it by means of a slanting neck seldom running directly upright. The whole was fastened to the end of the shaft by lashing in twine. Besides these plain examples, still others more decorated occur, many having bird forms, for example the hook of the arrow slings of the Ozonanes, now in Rome (see pl. IV, fig. 41). In the areas of these hooks there is a means of deciding the former distribution of spear slings. Some were found in Colombia, in Boyoca, and in Chile, on the borders of Ecuador; in Ecuador, in Culpi on the Riobamba, and in Azognes. It is from this area that Reiss brought the similar half-modern example from guano on the Riobamba. This ancient pattern seems to be that found in Quito, now in Rome.[b]

The third type is the Brazilian. It is still used in the chase, in tortoise-catching, and in war[c] among the peoples of the Magdalena and Amazon river district: (1) By the Tecunas, Cocamas, Combos, Campevas, Sorimoes; (2) by the Cauca and Patyagora stocks, and the Paez; (3) by the Canamaris, Purupurus, Paumari. It is still in use among the peoples of the upper Xingu and Araguaya; and (4) by the Aueto, Kamayura, Trumai, Suya, Karaya.

The spear slings of these four groups are of the male type, with a hole or pocket for the forefinger in the center of the under side. The first group shows quite a broad, thick shaft, flat above and arched below. It broadens perceptibly in the middle, and there is a good grip for the hand. On the under side of the middle is a rectangular cavity for the forefinger. A hook is attached to the upper side of the outer end (see pl. IV, fig. 42). This type was in use for tortoise harpoons,[d] among the Tecunas,[e] Cocamas,[f] and Conibos.[g] Perhaps the type of the Campevas or Omaguas and Sorimoes (in Teffe-Ega[g]). Stolpe[b] reports of these that their spear slings had a finger cavity. Spix and Martius[c] report that this type was similar to that of the

[a] Uhle: Intern. Arch., I, p. 209.

[b] Stolpe: Intern. Arch., III, pp. 234–238.

[c] Karl v. d. Steinen: Unter den Naturvölkern Centralbrasiliens; Uhle: Mitth. Wiener Anthrop. Gesell., XVII, after Oviedo.

[d] Bastian: Verhandlungen der Berliner Anthrop. Gesellschaft, 1884, p. 203.

[e] V. Spix und Martius: Reise in Brasilien, 1831, III, pp. 1024, 1187, 1193.

[f] Examples discovered, now in Berlin. See figure.

[g] Mason: Smithsonian report, pt. 2, 1884, p. 279.

Tecunas. Still, the latter also mention a groove or a cross piece, and isolated examples are found among old Indians of these tribes, who use them in fishing. The type of this class is not yet determined.

The second group embraces a type of which two examples were found in huacas, at Manizales, in southern Antioquia, now in the Copenhagen Museum.[f] They have the inner end thin and flat, with broad center piece as grip, in which is the finger hole and pointed end. The outer end is like a staff, and terminates in a knob with a scroll, into the upper surface of which a short, narrow groove is cut for the insertion of the hook (missing). A band passing across this held the hook still more firmly[a] (see pl. IV, figs. 43a and 43b). This, according to Bahnson, is the type of the Cauca spear sling. Uhle suggests that sling sticks with a groove probably existed in the Cauca Valley, and were in use among the Cauca tribes, and certainly in Antioquia, in the Aburra Valley opposite (according to Cieça, Robledo), to the south in Arma (according to Cieça), in the district of Ori, Cartama (on the left bank of the Cauca opposite Arma), Pozo to the south, among certain peoples related to the population of Arma (according to Robledo), Quimbaya, opposite Carthage (according to Cieça), and among the Pantagora tribes, on the upper Cauca and Magdalenian valley (according to Piedratuta); also by the Paez in the mountainous countries between these two rivers.[b]

In the third group the hole for the forefinger is placed in a space adjoining the grip. The shaft is flat like a ruler, broadish at each end and narrower in the midle. The hole for the forefinger, on the back, is between two cross bars. A small groove is supposed to have existed in some examples. The hook for the spear end is a tooth-shaped bone attached to the extreme end of the shaft (see pl. IV, fig. 44). In former times it was employed among the Purupurus (two examples in Vienna), Canamaris (a few examples still used in fish and turtle catching on the Jurua River in 1867 were encountered by Chandless), and by the Paumaris on the Upper Purus.[c] The fourth subclass is still in use. The shaft is a delicate rod (on the Araguaya it is angular in section), with broad flat handle incurved on both sides. Near the place where the grip changes into the shaft is a hole for the forefinger. Toward the upper end the shaft tapers to a point, where is lashed obliquely a small hook of wood or, among the Karaya, of bone (see pl. IV, fig. 45). It formerly served as a fighting weapon only, but is now mostly used in sport, and as such is very popular. The spear sling dance, called "yauari," also shows this, in which the wounding and death of a

[a] According to Bahnson; Intern. Arch. 11, pp. 217–227.

[b] All of these statements by Uhle: Mitth. Wiener Anthrop. Gesellschaft, XVII, pp. 107–114.

[c] Ehrenreich: Beiträge zur Völkerkunde Brasiliens, p. 51.

warrior with one of these weapons is portrayed.[a] Spears are not thrown with these, but a light arrow with a dull head for stunning. Instead of a point, a heavy stone or piece of wood is attached with cords and gum, or merely wax balls or tucum nuts serve as heads (see pl. IV, fig. 46). The shaft is often decorated at the upper hook with bunches of gay feathers. There is a smaller spear sling for children. Ehrenreich found such among the Karaya. This type, according to Karl v. den Steinen[a] and Doctor Ehrenreich,[b] is used among the Suya, Trumai, Kamayurá, Auötö on the Xingu, and by the Karayá on the Araguaya. In conclusion, there is still another spear sling from Brazil, of mixed type, which does not fit into this scheme and has nothing in common with the American spear slings. The shaft is flat on the upper side and half round below. It has a groove running the whole distance on the upper side, bounded by narrow lath-like borders. The outer end is flat and oblong and covered with a neat braid of cotton cords, which holds the peg firmly to the end of the groove. There is no distinct grip. The outer end of the shaft is decorated with two bunches of human hair (see pl. IV, fig. 47). According to Bahnson,[c] after comparison with two illustrations in the Copenhagen Museum, one may assume that it was indigenous to the tribes of the Tupi nation.

Thus, in Central and South America are three restricted areas of the distribution of the spear sling. The Mexican type extends from Utah to Panama; the second is indigenous to Colombia, Ecuador, and Peru; the third has been and still is used, in part, in Colombia, eastern Peru, northern and eastern Brazil. Each of the three types is in itself a complete unit, and the third in contradistinction to the other two. But between these three types themselves no relationship is discoverable; each is distinctly foreign to the other. A common prototype can not here be thought of. But a relationship between the shafts of the Eskimo and those of American type might be considered, as Mason suggests. Both are of the mixed type, and in the grip occurs here one or two, there one, finger hole. But all connecting links between the most southerly Eskimo shafts (Sitka) and the most northerly Mexican types (Utah) fail.

II. Projectile Slings and Thongs.

Another means of increasing the distance of flight and accuracy of aim is the projectile sling or thong.

Two principles are distinguished, the first serving to strengthen the propulsion. Small cords are loosely attached to the spear or

[a] Karl v. d. Steinen: Unter den Naturvölkern Centralbrasiliens, first edition, p. 231 et seq.

[b] Doctor Ehrenreich: Beitrage zur Völkerkunde Brasiliens, 1891, pp. 19 and 51.

[c] Bahnson, op. cit., Intern. Arch., 11, pp. 217–227.

small loops are tightly fastened. The second assists the rotation and the center of gravity by means of a longer cord wound around the spear, setting it in rotation when released.

The first type, which is used in war as well as the chase, is in two groups—(*a*) a throwing strap loosely attached to the spear; and (*b*) a cord fastened to the spear.

The first group is found in New Caledonia, New Hebrides, and New Zealand, with a variety in New Zealand and Hawaii.[a]

The projectile thong is a short cord braided from cocoa fiber or bat hairs, which has at one end a loop and at the other a knot, and which is called in New Guinea "sipp" (see pl. IV, fig. 49). The spear belonging to this, from 3 to 4 meters in length, has a hook back of the center of gravity, finely carved from the shaft, and usually representing a man's head; the spear also is beautifully ornamented with wrappings of hair and feather tufts. In use the loop is thrust over the thumb[b] or little finger,[c] while the knot is placed back of the hook on the spear. In throwing, the spear, grasped by the left hand near the point, draws the cord tightly toward the right. The releasing is accomplished as with the ordinary spear except that the cord assists the final rotation and the knot releases itself readily from the knob, so that by this "the force of the throw is much increased."[b] Forster (Vol. II, pp. 220 and 304) suggests that the projectile thong, after the knot was fastened back of the knob, was wrapped around the spear (see pl. IV, fig. 49).

A subclass, which shows the combination of the shaft and the projectile thong, occurs in New Zealand and Hawaii. Schurtz reports, in Urgeschichte der Kultur, that a simple wooden spear fastened to the snare with the aid of a stick was used in New Zealand, which released at the proper instant when thrown. This was called "kotaha," and the spear used in connection was called "kopere."

The second group shows a small leather loop fastened to the spear. It appears in Togo and in India. Numerous spears from Togo are found in the Leipzig Museum, 1.8 meters in length, with lanceolate iron point and a long iron spud. About 20 centimeters back of the center of gravity there is a small leather loop about 4 centimeters in length (see pl. IV, fig. 50). No literature on these spears is at hand and about their use nothing is known. Egerton (Handbook of Indian Arms, p. 12, pl. 2, fig. 6; and p. 79, pl. 72, figs. 72 and 75) gives numerous illustrations of spears from India which also have a loop

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[a] New Caledonia: Forster, Waitz, Schurtz. New Hebrides: Meinicke, Eckhardt, Forster, Gray (Some Notes on the Tannese. Intern. Arch., VII, p. 225 f.). New Zealand: Bastian. New Zealand and Hawaii: Schurtz, Doctor Arning.

[b] Waitz: Anthrop. der Naturvölker, VI, 597 et seq.

[c] Eckhardt: Der Archipel der Neu-Hebriden. Verhandlungen des Vereins for naturw. Unterhaltung zu Hamburg, 1877, Vol. IV.

around the shaft. In the spear on page 12 (next to fig. 1) the long loop is shown quite near the point, while in the spears of the Dravida and Tamuls, on page 79 (figs. 2 and 3), quite broad flat loops are found at about the center of the spear.

The second type of projectile noose aids the spear in attaining a forward rotary motion. We come upon it in the roller straps of the Greeks and Romans. The spear thong seen with this is called "hasta amentata."

The thong spear was originally in use in Greek gymnasiums, then it became a hunting weapon of the northern hunting peoples (Ætolians, Acarnanians, Locrians, Thessalians, Thracians, Scythians, etc.), until it was finally adopted as the universal projectile weapon of the peltasts. It was also sometimes employed by horsemen. Among the Romans it was first adopted through Pyrrhus, and from then on was the standard weapon of the light armed, who carried five to seven.

The tragula of the Gauls seems also to have been such a strap spear, according to Cæsar.[a] It is pictured by numerous writers, as well as in plastic and pictorial illustrations, i. e., in the vase pictures of the British Museum; bronze disk picture of Ægina, in Berlin; Etruscan vase (illustrated by Hamilton III, 33); pictures on vases copied by O. Jahn, Millingen; grave pictures from Paestum, copied by Springer (Kunstgeschichten I, p. 115); and the slaughter of Alexander, in mosaic. The spear, upon which the strap was buttoned, was probably, with the point, about 4 feet long and but a finger breadth in diameter. The point was usually extremely long, thin, and fine, so that it bent after the first throw, which made it impossible to use it a second time. The thong was narrow, cut from leather, at the most an ell in length, and the ends were usually sewed, buttoned, or buckled together. The strap was tightly fastened to the spear by means of a single or double wrapping, back of the center of gravity, therefore at different parts of the spear, according to the weight of the iron point. In throwing, the noose was drawn taut, whereby the rotation was caused, the strap unwinding itself and revolving the spear lengthwise. The strap remained hanging to the spear, the more seriously injuring the wounded.

[a] Cæsar: De bello Gallico, V, cap. 48.

MATERIALS USED TO WRITE UPON BEFORE THE INVENTION OF PRINTING.[a]

By Albert Maire,
Librarian of the University of Paris.

The subject treated here is not new; it is to be found, indeed, in many works, or scattered in special reviews, in monographs, and notes upon the history of writing and upon the methods and materials used for that purpose. But a synthetic presentation of this knowledge in a definitive form has thus far not been attempted. It is at once curious and instructive; connected, on the one hand, with the history of the evolution of languages and of writing, and, on the other, with a portion of human industry. It is, in a word, a contribution to the sociological history of mankind.

The patient research of linguists and the comparative study of the most ancient styles of writing have led to the enunciation of the idea that certain signs or rudimentary drawings of a kind still used by the uncivilized of our day were employed at the very origin of writing—pictographic writing.

First let us have a definition of writing; the one Monsieur Philippe Berger gives: "It is the art of fixing the word by conventional signs, traced by the hand, which are termed characters. Characters may represent ideas or sounds. We term ideographic writing such as is used to give us the ideas directly; phonetic writing, such as expresses by characters the sounds of the word. Writing differs from design in that it is inseparable from language. If, in ideographic writing, the characters are pictures of certain ideas or certain objects, they are recalled to the mind under the form which they assume in speech; that is to say, through the medium of the word. All systems of writing which were in the beginning purely ideographic became, by degrees, syllabic. The distinction between alphabetic and non-alphabetic writing is the only one which corresponds with historic reality."[b]

[a] Translated, by permission, from Revue Scientifique, Paris, August 13–20, 1904.

[b] Histoire de l'écriture dans l'antiquité, Paris, 1891, Introduct., pp. XIII, XV.

We can not here relate the history of the evolution of the various styles of writing; the aim of these pages is to make known the materials that have been used to write upon.

In giving the history of the materials and processes which have brought down to us the annals and ideas of humanity, this description of the methods adopted by man to develop the expression of an idea and to make that idea penetrate simultaneously the intelligence of the human species becomes a history of humanity itself.

Do we not return to the source of this humanity, of its beginnings and its progress in civilization, in seeking the manner in which thought came to be fixed in tangible form and transmitted through the ages? Before the first peoples with a history—the Egyptians, Assyrians, Medes, Persians, Chinese, Hindoos, American Indians—research is little more than hypothesis. An impenetrable obscurity rests over those distant times in which man was concerned only with his material wants.

Man looked round about him. From the first nature offered him products which asked only to be utilized. Stones and marble, metals, wood, the bark of trees and their leaves, the skins of animals and their intestines, tissues, and artificial products of all kinds contemporaneously or successively received the impress of sculpture, painting, or the inscription of human actions and thoughts. In every case where it is possible to cite an example we shall do so. Some figures which complement the facts adduced, and will perhaps be helpful to a comprehension of the subject, have been scattered through the text.

FIG. 1. Wampum.

But before starting in on any methodical plan we must speak of some mnemonic devices which bear a distant relation to writing. They were, however, intended to perpetuate the memory of the deeds or condition of an individual.

Wampum (fig. 1), a sort of collar or belt, made of different colored shells arranged in a definite order and presenting geometrical figures, signs which were all symbolic and significant, was utilized by a part of the Indian tribes of the United States, Canada, and Central America. According to Stearnes, wampum was employed as money by the aborigines of the Carolinas, Virginia, etc.[a]

The Peruvians and the greater part of the different peoples of

[a] Smithsonian Report, Museum, 1887, p. 304 et seq.

South America used grains of corn or variously colored pebbles, which they arranged in a certain order, for the purpose of expressing certain ideas, transmitting messages, or recounting the great deeds of their nation. Later these same peoples employed strings of varying lengths and colors, in which they made knots and loops at greater or less intervals. This is called the "quippo."

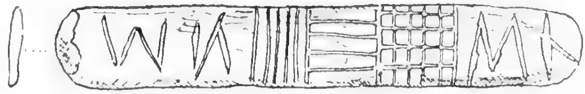

FIG. 2. Australian message stick.

We must mention likewise the small sticks of the Scythians, the stick of memory; "stick messages" of the Australians, means employed to correspond at a distance. (Fig. 2.)[a]

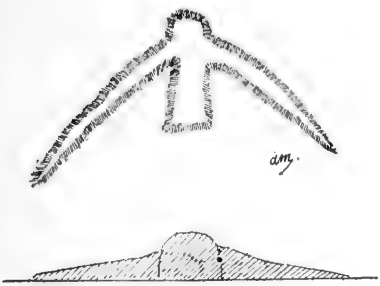

FIG. 3. Bird mound near Milwaukee.

What shall we say of the mounds (fig. 3),[b] raised burial places, of North America, abounding particularly in Ohio and Wisconsin, and the outline of whose base assumes the shape of an animal—quadruped, bird, serpent, lizard, or turtle? It is permissible to suppose that these forms designated the totem of the tribe or the individual who reposed in these tombs.

The strangely shaped rocks, with a length of more than 12 kilometers, which project from the waters of the Nam-Ou, in Upper Laos (fig. 4),[c] and the trees and bushes cut in the shape of animals which one sees on both banks of the river, are indeed rather difficult to explain.

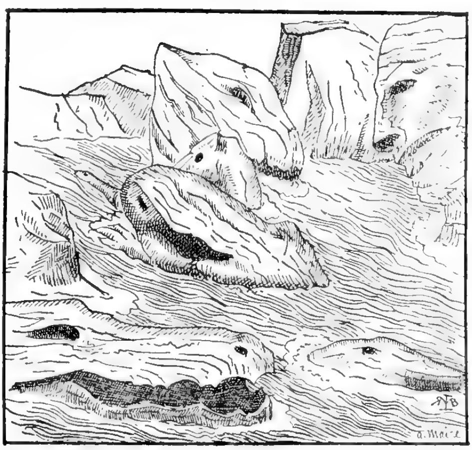

FIG. 4. Rocks hewn in the form of animals and the human head in Nam-Ou.

After this digression, somewhat beside the subject, but nevertheless necessary, let us return to the materials upon which writing has been done.

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[a] Roth (W. E.): Ethnological Studies Among the North-West-Central Aborigines. Brisbane, London, 1897, 8°, pl. XVIII, No. 32.

[b] Lapham (I. A.): The Antiquities of Wisconsin (Smithsonian Contributions to Knowledge, 1885, 4°, Vol. VII[5]).

[c] Neis (P.): Voyage dans le Haut-Laos (Tour du Monde, 1885,[2] pp. 51 and 83).

ROCKS, CRUDE AND PLANED, BUT NOT DETACHED.

The rupestrine inscriptions, probably the most ancient of all, are found in nearly every portion of the globe, more particularly in Asia and Europe. Those that belong to the prehistoric period are traced or engraved directly upon the rough face of unplaned rock. We may name as examples the cup rocks of Hohenstein, at Swansen (German Holstein);[a] the sculptured rocks of Tegneby, in Bohuslän (fig. 5),[b] and those of the "Ramsundsberget" Mountain, in Södermanland (Sweden). Some of these inscriptions were known in the seventeenth century, for they were copied in 1627.[c]

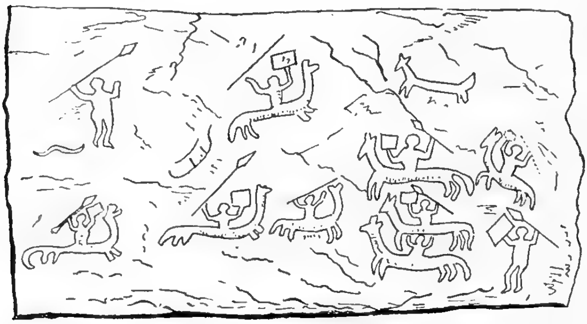

FIG. 5. Designs on rock at Tegneby, Bohuslän, Sweden.

The designs and figures engraved upon the granite masses on the banks of the Yuba River in New Mexico are to be classed in the category of pictographic writing (fig. 6).[d]

In central Asia, Egypt, Assyria, and Persia, on the other hand, the rocky surfaces intended to receive inscriptions were carefully planed and prepared; the inscriptions therefore stood out very distinctly on the body of the rock. Such is the case with the famous inscription of Behistoun in the pass that separates Persia from Mesopotamia,[e] the edicts of Açoka, engraved upon the rock at Girnar, in Guzerat (India).[f] We must not neglect to mention the subterranean temples cut into the rocks.[g]

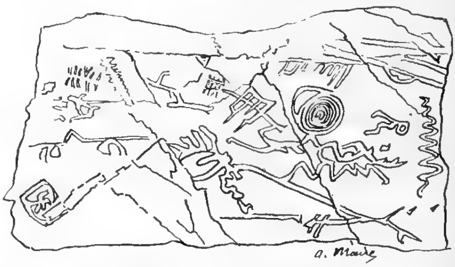

FIG. 6. Fragment of a hieroglyphic inscription made by California Indians on a granite rock.

[a] Zeitschrift f. Ethnologie, Vol. IV, 1872, pl. 14.

[b] Montelius (Oscar). La Suède préhistorique, trad. J. H. Kramer, Stockholm, s. d., 8°, p. 64 seq.

[c] Revue archeol., 1875, p. 137 seq.

[d] Simonin (L.). De Washington à San Francisco (Tour du Monde, 1874, p. 240).

[e] Morgan (J. de). Mission scientifique en Perse (T. IV).

[f] Berger (Phil.). Op. cit., p. 224.

[g] Perrot (G.), Chipiez. Hist. de l'art dans l'antiquité: I. Egypte, 1882, p. 411 seq.

the tombs of the same kind, so numerous in Egypt, in lower Asia, and India. Most of these monuments are covered with inscriptions of greater or less length.

DETACHED ROCKS AND MEGALITHIC MONUMENTS.

DESIGNS, CUPS, AND BASINS, PICTORIAL AND SYMBOLIC INSCRIPTIONS.

These monuments are more numerous than the preceding. We find them scattered over every part of the earth; man has erected

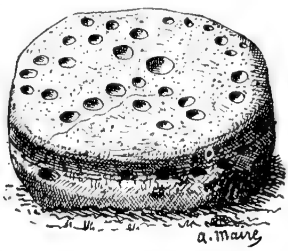

FIG. 7. Carved rock near Falkoping, West Gothland, Sweden.

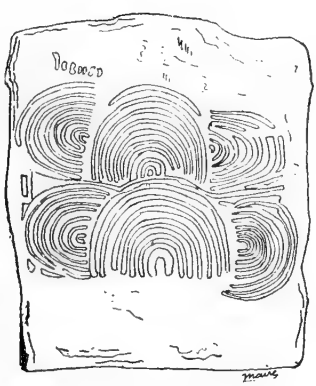

FIG. 8. Dolmen. Gavr 'Inis, in Baden.

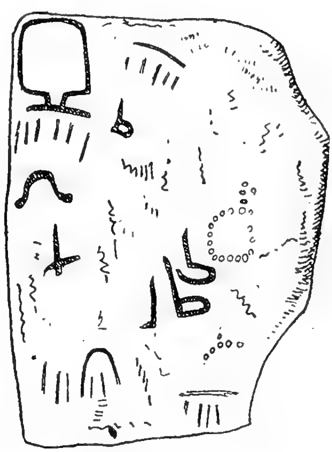

FIG. 9. Mané Lud dolmen in Locmariaker.

megaliths wherever he has found stone. Selecting at random among the numerous representations of monuments of this kind, we shall call attention to a few, by way of example. Ballersten de Rantœn (fig. 7),[a] near Falkoping, in West Gothland (Sweden); one of the dolmen stones of Gavr 'Inis, in Baden (fig. 8)[b]; another of the Mané Lud (fig. 9),[c] in Locmariaker; the Dead Man's of Vanga

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[a] Montelius (Oscar). Der Orient und Europa, uberg v. Metsdorf. Stockholm, 1896, 8°, p. 28.

[b] Diction. archéol. de la Gaule. Atlas.

[c] Ibid.

(fig. 10),[a] in West Gothland, which presents runic characters of the third century of our era; the upright stone of St. Dogmaël, in Pembrokeshire (Wales), upon which are found two inscriptions, one in Ogham, the other in Latin characters;[b] that which we here reproduce (fig. 11) is from an article on the "Oghama inscriptions at Kenfegge, in Glamovganshire;"[c] finally, the numerous sculptured dolmens of Ireland (fig. 12).[d] Abbé Domenech, in the curious account of his sojourn of several years among the Indians of North America, speaks of tombstones bearing pictographic characters (fig. 13)[e] and of strange inscriptions upon flint stones (fig. 14).[e] To the cliff dwellers, or inhabitants of caves, of Arizona and New Mexico are attributed the designs and pictorial engravings found upon the rocks borne to the

FIG. 10. Dead man's name. Rock with runic characters found at Vanga, West Gothland, Sweden. Height, 3 feet 5 inches; width, 8 feet.

banks of the San Juan (fig. 15).[f] Quite recently there were brought to light the stones of St. Aubin Baubigné (Deux Sèvres) (fig. 16),

[a] Stephens (Dr. G.). Handbook of the old northern runic monuments of Scandinavia and England. Edinburgh, 1884, fol.

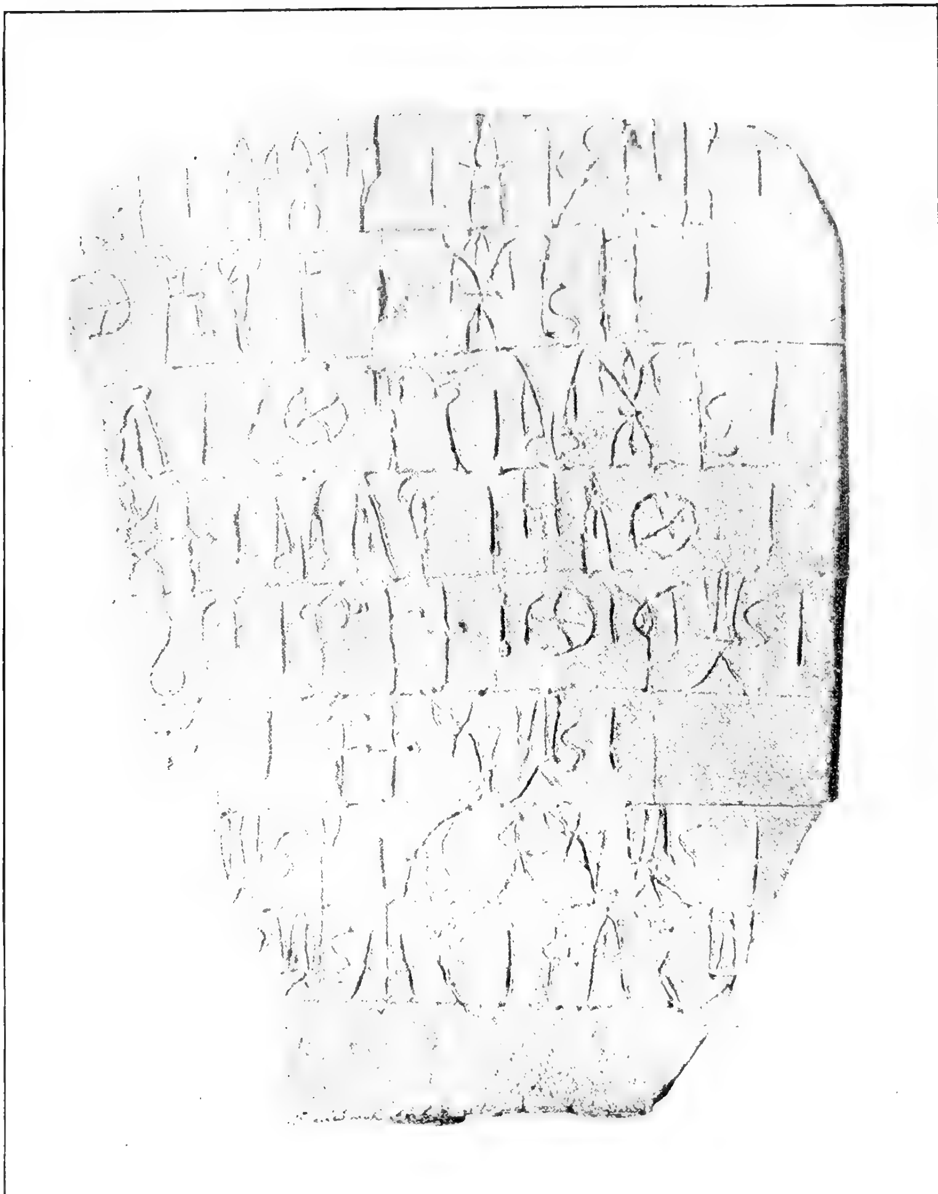
[b] Brash (Rich. R.). The ogham inscribed stones of Wales. Archæologia Cambrensis, 3° series, Vol. XV, 1869, p. 155.

[c] Archæologia Cambrensis, 1846, Vol. I, p. 412.

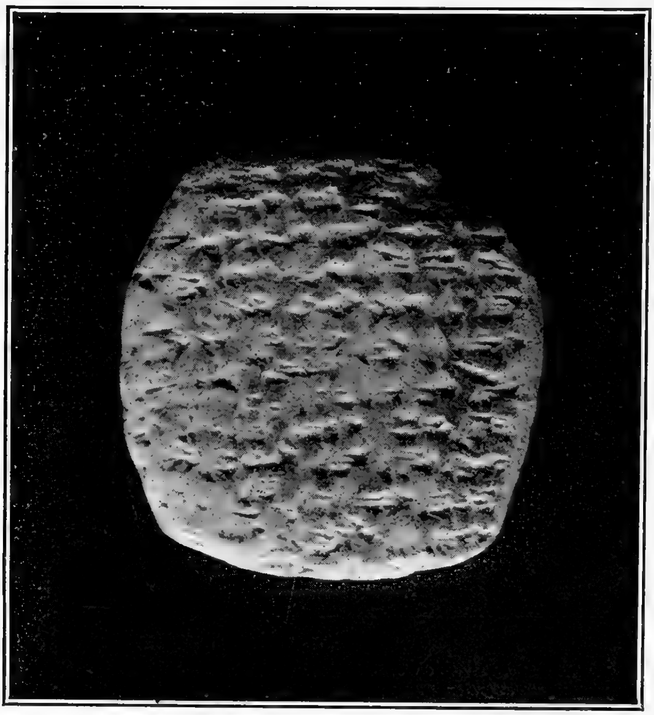
[d] Borlase (William Copeland). The dolmens of Ireland. London, 1897, 3 vol. 8°, fig.

[e] Domenech (Abbé). Seven years' residence in the great deserts of North America. London, 1860, 8°, 2 vol.

[f] Nadaillac (Marquis de). L,Amérique prehistorique. Paris, 1882, 8°.



CLAY TABLET WITH THE PREHISTORIC LINEAR SCRIPT.



CUNEIFORM TABLET OF CLAY FOUND AT LACHISH.

upon which inscriptions are distinguished which have formed the subject of a communication to l'Académie des Inscriptions et Belles-

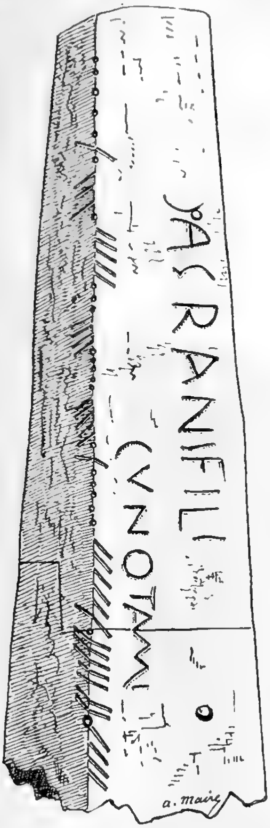


FIG. 11. Inscription in Latin and Ogham. St. Dogmael, Pembrokeshire.

FIG. 12. St. Monaghan's stone. Ireland.

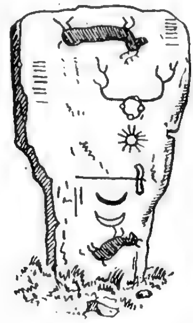


FIG. 13. Pictographic inscription on a grave stone.

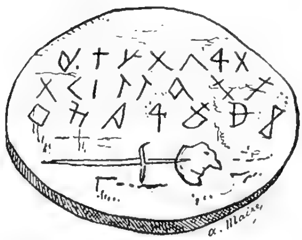


FIG. 14. Inscription graven on rock by North American Indians.

Lettres, and of which the journal l'Eclair reproduced three designs in its issue of the 1st of April, 1904.[a]

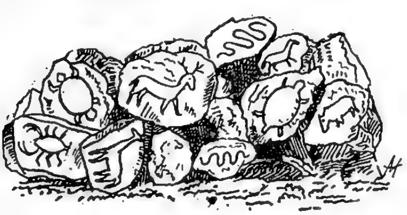


FIG. 15. Carved rocks on banks of San Juan River, Arizona.

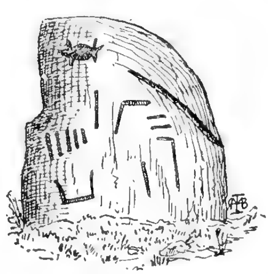


FIG. 16. One of the carved blocks at St. Aubin Baubigné (Deux-Sèvres).

[a] Communication of Doctors Capitan, Breuil, and Charbonneau, session of the 11th of March, 1904.

ROCKS CUT INTO TABLES OR BUILDING STONES.

It requires no great effort to find inscriptions of this kind. As civilization developed, man began to prepare with care the material upon which he wished to write or carve. Throughout the Orient, from Egypt to India, monuments constructed of dressed stones are covered with carvings or pictures, explained and commented upon by inscriptions (fig. 17). The Greeks and the Romans employed stone tables for the purpose of engraving laws, public and commemorative records. The funeral cippi and stelæ of nearly all nations are covered with inscriptions, and likewise the coffins of stone and wood.

Are not our modern cemeteries like an immutable obituary, or, better still, like a huge biographical dictionary?

Inscriptions upon stones of all kinds—marble, sandstone, granite, slate—are so frequently met with around us that it seems superfluous to cite examples.

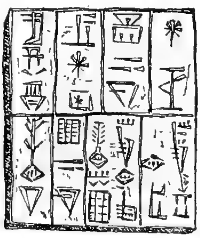


FIG. 17. Brick from Erech. (Perrot and Chepie, Histoire de l'Art. Paris.)

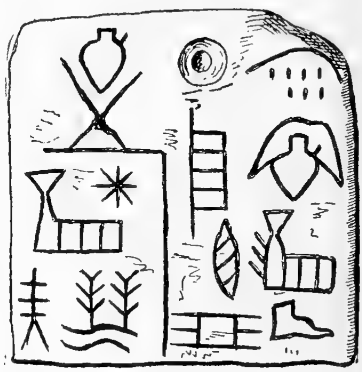


FIG. 18. Babylonian hieroglyphic tablet.

The baked earths deserve special mention on account of their preparation and their antiquity. In ancient times the Persians, Medes, and Assyrians were about the only nations that customarily made use of clay, either dried or baked, for writing upon (fig. 18)[a], inscriptions of this kind are known which date back to more than four thousand years before Christ. These countries were so poor in rocks that all their structures were built of brick.

Ceramics were still in their infancy when designs and symbolic signs were employed for decoration. Everyone is familiar with the geometrical designs, the crossed, dotted, or concentric lines which ornament prehistoric pottery.[b] The ceramics discovered at Hissarlik and Mycenæ present strange decorations; one finds colored and concave designs, swastikas, and inscriptions in archaic characters

[a] Schell (V.) O. P. Notes d'épigraphie et d'archéologie assyriennes. Reprint from: Recueil de travaux relatifs à la philologie et à l'archéologie égyptienne et assyrienne, 4°, t. XXII.

[b] Consult the collection: Matériaux pour l'histoire primitive de l'homme.

(figs. 19–20);[a] the same remarks are applicable to the ceramics of Central and South America (fig. 21);[b] peculiarity of shapes and designs, paintings and symbolic characters.

In Grecian antiquity fragments of pottery were utilized as materials upon which to write accounts and observations (fig. 22);[c] the beautiful Grecian ceramics of the purest period always bear inscriptions explanatory of the figures.

METALS.

It can not be demonstrated that iron never received engraved inscriptions in antiquity. The great decomposition which this metal must have suffered under the influence of the oxygen of the atmosphere and the earth is the only reason why none has come down to us.

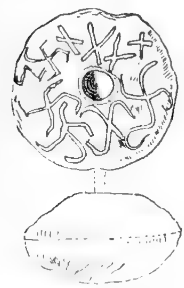


Fig. 19. Fusaiole with archaic inscriptions.

Fig. 20. Fusaiole with archaic inscriptions.

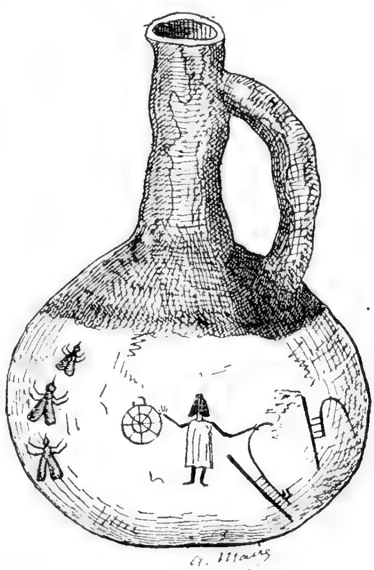


Fig. 21. Bolivian vase. (Castelnau Exped. de la partie centrale de l'Amerique du Sud. Paris, 1882.)

Fig. 22. Pottery fragment with Greek inscription.

All the other metals, including the precious metals, pure or alloyed, are found with inscriptions. There have been recovered in Egypt, Assyria, Central Asia, and Greece tables or placques of bronze which were covered with them. Hannibal had lengthy Greek and Punic inscriptions engraved describing the state of his army and his

[a] Schliemann. Ilios, Ville et Pays des Troyens, trad. de l'anglais par Mme. Egger. Paris, 1885, gr. 8°.

[b] Castlenau (Fr. de). Expédition dans la partie centrale de l'Amérique du Sud. Paris, 1852, 8° et 4°, atlas, pl. 11, 12, 13, 14, 16.

[c] Wilken (Ulr.). Griechische Ostraka aus Aegypten u. Nubien, Liepzig, 1889, 8°. Vol. II, pl. 1 to 3.

series of exploits.[a] In Rome the use of columns and of tablets of bronze for inscribing laws followed that of wood. We find in all the museums of Europe inscriptions upon metals (fig. 23). One of the most remarkable is the famous bronze tablet preserved in the Museum of Lyons, containing the address delivered in the year 48 by the Emperor Claudius.[b]

Lead beaten thin and reduced to leaves served the same purpose. Job laments his inability to write a discourse upon sheets of lead. In Greece lead thus prepared was quite frequently used. Suetonius terms these leaves of lead plumbea charta;[c] tablets were also made of it, which were employed all through the Middle Ages.

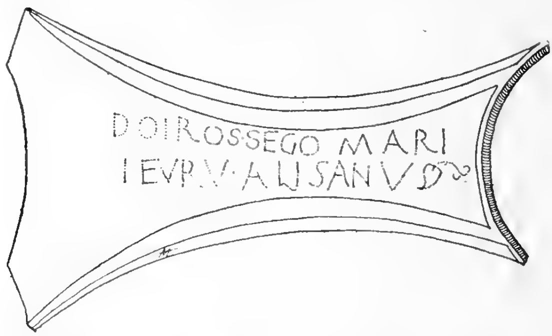


FIG. 23. Gallic inscription in dotted characters on bronze found near Dijon. (Dict. Arch. de la Gaule.)

It seems unnecessary to cite coins and medals. They always bore a legend, either symbolic or explained by letters.

WOOD, BARK, LEAVES.

Wood as a material used to engrave and write upon is perhaps more ancient than stone, but there is no trace of it left from the prehistoric period. It was split into thin boards, upon which were traced in different colored inks the characters of the language. The Egyptians must have proceeded in this manner, if one may judge by a sycamore board discovered in 1837 in the third pyramid of Memphis, which, according to the Egyptologists, dates back more than five thousand years.

The ancient laws of Solon and of Draco were likewise traced upon wooden tables. They were called "axones." These tables joined in the shape of quadrangular prisms and crossed by an axis, were first set up perpendicularly in the citadel, where, revolving by the slight-

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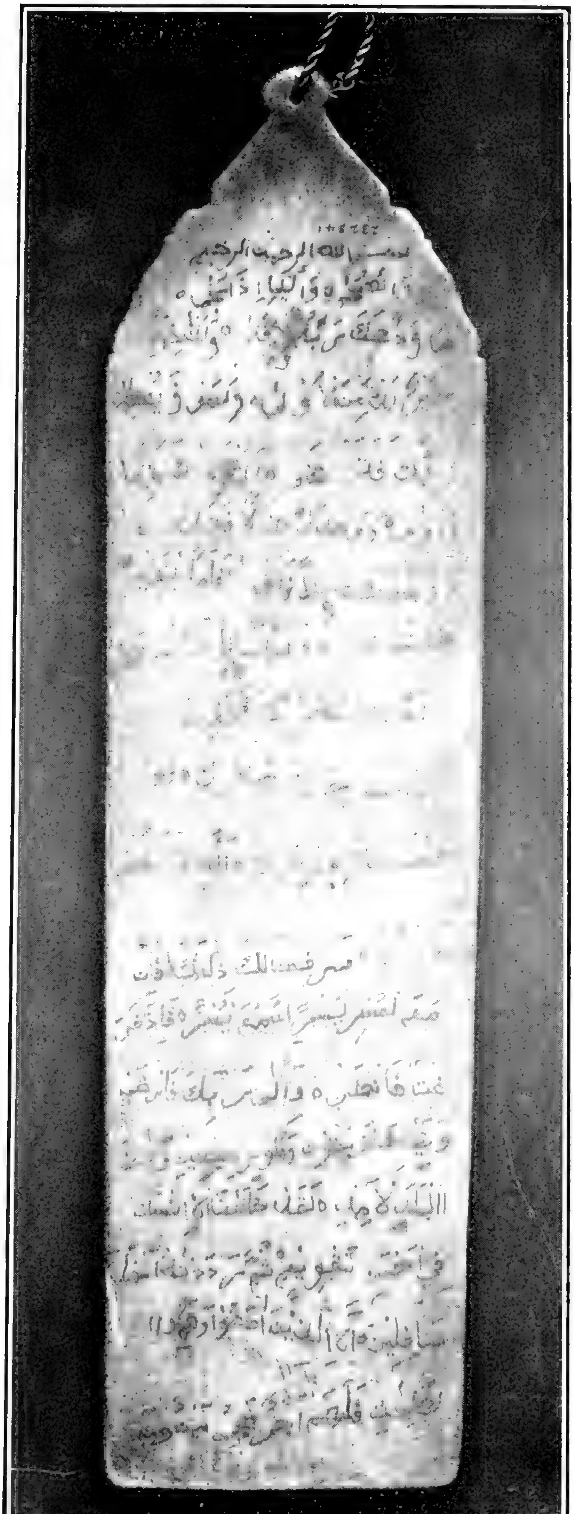
[a] Polybius, III, 33.

[b] Allmer (A.) et Bissard (P.). Musée de Lyon. Inscriptions antiques. Lyon, 1888 seq. gr. 8°, t. 1, p. 58 seq. and 1 plate.

[c] Suetonius. Twelve Cæsars. Nero, C. 20.

BABYLONIAN VOTIVE TABLET OF THE SUN-GOD AT SIPPARA, ENGRAVED ON ALABASTER.



ARABIC SCHOOL EXERCISE INSCRIBED ON BOARD.

From Philippine Islands.

est effort, they presented successively the entire code of laws to the eyes of the beholders. (Fig. 24.)[a]

In Rome the laws were written upon boards of oak, which were exhibited in the Forum. The word "album" probably originated in the Roman custom of inscribing in black ink upon tablets of wood, painted white, their annals or daily happenings.[b]

St. Jerome informs us also that small boards and cubes of wood were employed to engrave the alphabet upon, to teach the children to read.

The tablets in use among the Romans and throughout the middle ages were made of wood. They were likewise made of lead, ivory,

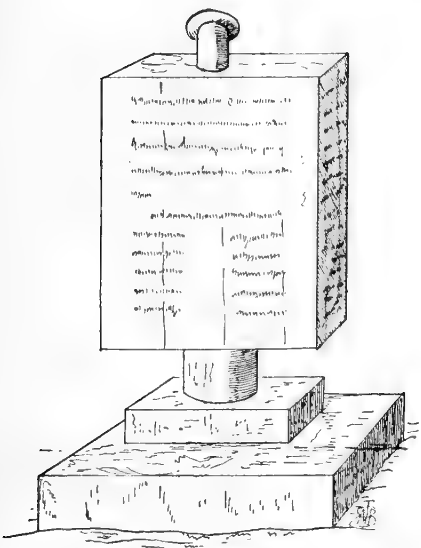


FIG. 24. An attempt at a restoration of the tables of Solon (Azores) from Géraud's description.

FIG. 25. Wood tablet with Greek inscription.

parchment, and even of the bark of trees. In the time of the poet Fortunatus not only were tablets of ash used, but small, smooth rods as well.[c]

The Egyptians observed the custom of putting "tablai" (fig. 25)[d] upon their coffins. These tablets contained the names and attributes of the deceased person. All that have thus far been collected seem to date from the Roman occupation, since the inscriptions are in Greek.

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[a] Géraud (H.) Essai sur les livres dans l'antiquité, Paris, 1840, 8°, pp. 19–20.

[b] Géraud, op. cit., p. 20.

[c] Ibid., p. 21.

[d] Le Blanc (Edm.), Revue archéolog., 1874, p. 242 et seq.

Shavings of wood, taken off by the plane, were also utilized. Theophrastus cites an example of it,[a] and Pancirot says that the Lombards joined these shavings by means of glue and thus manufactured a sort of paper.[b] The idea of writing on wood is not lost in our days. Entire books are written on leaves of wood resembling thin veneer. Visiting cards of wood are sometimes seen. In China paper and envelopes are used where the paper is exceedingly thin and is covered with a pellicle of wood. The school primers of the East—Algeria, Turkey, and other Moslem regions—are made of small boards (pl. IV), recalling in form the Egyptian tablai, upon which the letters or sentences from the Koran are written. The inscriptions, which are so curious, but which have not yet been deciphered, discovered on Easter Island, are engraved upon wood. Wood is even at the present day employed in China for engraving characters in relief, which are subsequently printed. Our xylographic plates of the fifteenth century were also of wood.

Finally, wood is still employed to make blackboards, in use in schools.

In the remotest times the ancients used the outer bark of trees for writing, but the numerous inequalities and the frequently great fragility of the bark caused it to be abandoned, with the exception of that of the cherry, the linden, and the birch. They sought to utilize the inner bark, or liber, of the tree, and employed by preference that of the pine, the fir, and the linden.[c] The Greeks and the Romans wrote extensive works upon the prepared bark of trees.

The leaves of trees have also been used. The Syracusans voted by writing on olive leaves, whence the word petalism, a synonym of ostracism.[d] The leaves of several other trees, among them the mallow, contributed to the same purpose. A sort of tissue was made from the leaves of a certain palm.

In Persia, a great part of Asia, India, Indo-China, China, Borneo, Sumatra, even in Oceania, prepared leaves of trees, particularly of certain palms, were and are still made use of. In Malaysia they use the leaves of cabbage palms, dried, polished, or covered with a brilliant or gilt varnish; it is after these successive preparations that they trace the characters with a pencil or engrave them with a very fine point. Certain books, formed thus, resemble a good deal the slats of our Venetian blinds, opening and closing in the same manner. In the Maldives they use the leaf of the makarekau, which has a breadth of 1 foot and a length of 3 feet.[d]

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[a] Géraud, op. cit., p. 21.

[b] Ibid.

[c] Géraud, op. cit., pp. 16, 17.

[d] Ibid., p. 15.

LINEN AND OTHER TEXTILES.

It was natural enough that textiles should be used for the tracing of characters with a pencil or calamite. Their flexibility and the facility of preserving them adapted them to it. Most of the "books of the dead" which the Egyptians placed in the sarcophagi were written upon linen. In Greece, Italy, Rome, and the Orient textiles served the same purpose. The Samnites had a ritual written in that manner, which served to regulate the order of the sacrifices before engaging in a war.

At Rome the land records preserved among the archives were written upon linen year by year and kept in the temple of Moneta at the capital,[a] as well as the libri lintei, a list of the magistrates. Textiles were used even for transcribing literary works. Martianus Capella designates them under the name of carbasina volumina. Sidonius Apollinaris wrote his poems upon pieces of linen. During the middle ages this custom still continued, for an abbot recommends his monks to copy the works of St. Anastasius upon their clothes in case paper should be lacking.[b] In the Orient silk was utilized for the same purpose. "In France," says Géraud, "up to the last century, it was the practice in the universities to have those copies of a thesis which were intended for personages of importance printed on satin.[c]

We have spoken incidentally of tablets; they were made of wood, lead, ivory, and even parchment, and, excepting those of lead, were coated with wax, and written upon with a point or stylus. To preserve them, they were placed together and tied into bundles. In order that the writing should not be obliterated under pressure or by rubbing, the edges of the tablet had a slight projection to which the wax flowed; so that the engraved characters were not effaced when the tablets were pressed together. Later the tablets formed a diptych; that is to say, they were composed of two tablets united by a hinge. Closed, they presented two surfaces, plain or ornamented, but without writing; open, one could write upon both of the wax-covered inner surfaces.

LEATHER, VARIOUS KINDS OF SKIN, PARCHMENT.

With the advent of skins we enter upon a period in which writing becomes a more common practice; documents multiply, works of the imagination and historical annals assume a new form. It is no longer tradition alone which transmits poems, legends, and recollections. By

[a] Lafaye (G.): Article Liber, Diction des antiq. grecques et romaines de Daremberg et Saglio. Paris, Hachette, 4°.

[b] Lalanne (Lud.). Curiosités bibliographiques. Paris, 1857, 16°, p. 10.

[c] Géraud. Op. cit., p. 23.

the use of skin and its various preparations, manuscripts are recopied and circulate among all classes of ancient society.

For a long time skins rudely prepared, scarcely tanned, were used for writing. We know through documents that the Egyptians employed them two thousand years before our era; the Assyrian monuments depict scribes writing on scrolls. The Persians recorded their annals upon hides, while the Ionians prepared for the same purpose the skin of the sheep and the goat. According to biblical texts, the Hebrews were accustomed to the use of skins, and copied their law upon rolls of leather [a] (pl. v). "There is preserved," says Lalanne,[b]

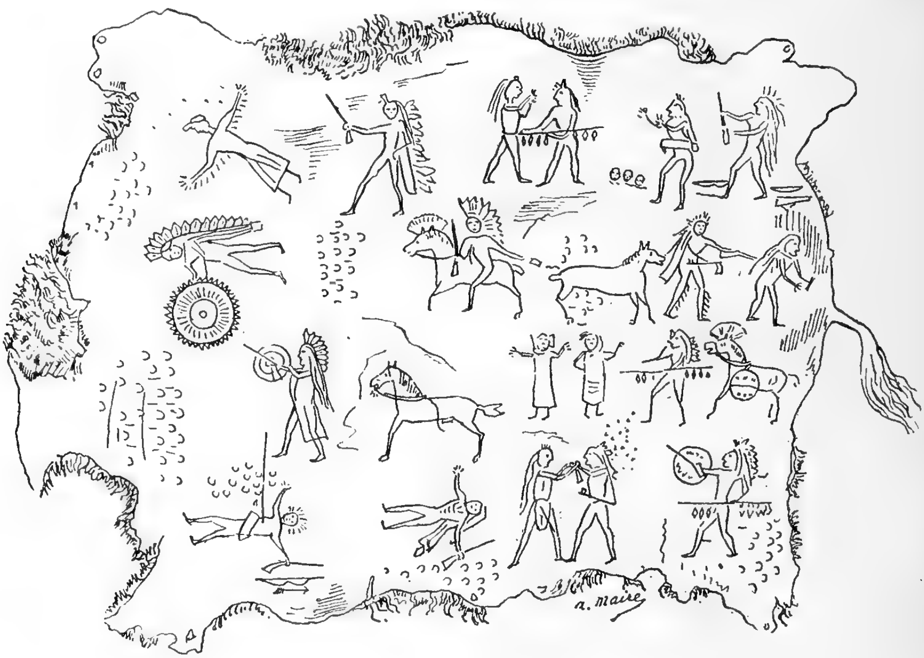


FIG. 26. Buffalo skin figured with designs showing a war chief in action.

"in the library of Brussels, a manuscript of the Pentateuch, which is believed to date back beyond the ninth century. It is written on 57 skins sewed together, and is 36 meters long."

Petrarch wore a vest of leather upon which he wrote his inspirations when on a walk. This vest, covered with writing, was in 1527 still in Sadoleto's possession.[c]

Let us recall that the red-skin Indians wrote or painted the results of the chase or their martial exploits on the inside of the tanned and bleached skin of the bison (fig. 26)[d], which served them for a

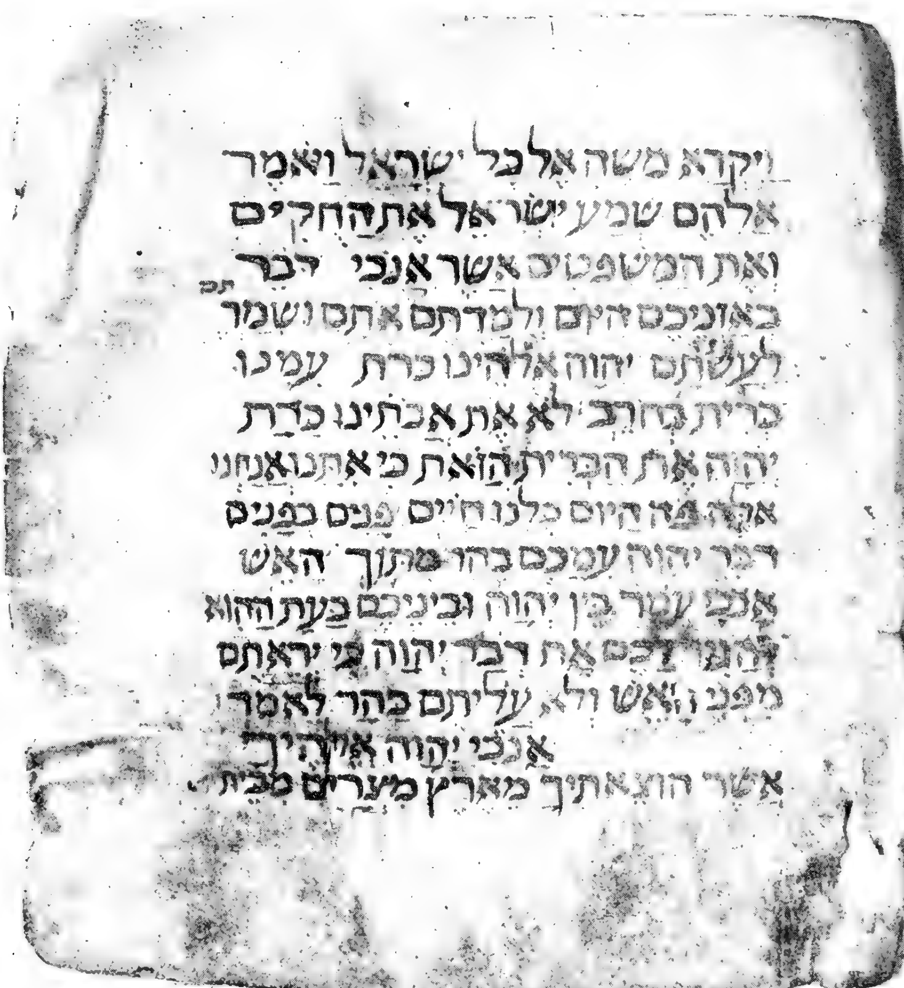
[a] Hasting (James). A Dictionary of the Bible. Edinburgh, 1902, Vol. IV, art. Writing.

[b] Lalanne (Lud.). Curiosités bibliogr., p. 10.

[c] Géraud, op. cit., pp. 9–10.

[d] Catlin: North American Indians, 1832–1839. Edinburg, 1903, 8°, 2 vols.

HEBREW MANUSCRIPT OF THE PENTATEUCH, WRITTEN ON UNBLEACHED LEATHER.



ויקרא משה אל כל ישראל ויאמר
אלהם שמע ישראל את החקים
ואת המשפטים אשר אנכי דבר
באזניכם היום ולמדתם אתם ושמר תם
לעשתם יהוה אלהינו כרת עמנו
ברית בחרב לא את אבתינו כרת
יהוה את הברית הזאת כי אתנו אנחנו
אלה פה היום כלנו חיים פנים בפנים
דבר יהוה עמכם בהר מתוך האש
אנכי עמד בין יהוה וביניכם בעת ההוא
להגיד לכם את דבר יהוה כי יראתם
מפני האש ולא עליתם בהר לאמר
אנכי יהוה אלהיך
אשר הוצאתיך מארץ מצרים מבית

FRAGMENT OF HEBREW MANUSCRIPT ON PARCHMENT.

cloak. In certain islands of Polynesia, and particularly in New Zealand, the tattooing of the men was governed by the brilliancy of their deeds. The designs, which covered the face and the body, represented symbolically a description of events. Even the human skin has incidentally been used to write upon. Between tanned skin and parchment there was but a brief interval. In order to diminish the weight of the leather, man first had to thin it. Then he tried to bleach it—hence the origin of parchment. It is possible that it was at Pergamus the improvement was made. They must have manufactured it and dealt in it there, since the product derives its name from that place. It is believed that it was known fifteen centuries before the present era.

The skin of the goat, the sheep, and the ass was prepared by methods nearly identical with those of our own day.[a] The first productions of parchment were so defective that they were only used to cover books made of papyrus and tablets and for labels. It is only toward the fifth century before our era that the practice of writing on parchment became general. As its preparation improved its use spread more and more. After the eleventh century this material entirely supplanted papyrus, which had become rare and poor. We know that books of importance, manuscript and printed, are composed of parchment. Up to the eighteenth century it was always used for royal acts and private transactions.

PAPYRUS.

It is from the stem of the *Cyperus papyrus* (paper rush) that according to Baillon, paper was manufactured. This rush, a native of Egypt, it is said, was very abundant up to the middle ages, but it has become rare and is not met with except on the marshy banks of streams in the far south. The root, as thick as a man's arm, spreads out horizontally, the stalks rise from it at right angles to a height of from 7 to 10 cubits[b]—that is, about 3.6 to 4.5 meters. The slender stem, tenuous, triangular almost through its entire length, is terminated by an umbel composed of green filaments, producing a most beautiful effect. But it is not in Egypt only that the papyrus was found, it grew in Sicily, Spain, the southern part of France, as far up as Avignon, in the shallows of the Rhone,[c] as well as in the greater part of the streams of Africa and Madagascar.[d]

[a] Lafaye, Art. Membrana., Dictionn. des antiquités grecques et romaines.

[b] The Greek cubit varied from city to city; its average length was 0.43 centimeters.

[c] We gathered some in 1879 near the gate of the Oulle at the base of the bridge which leads from Avignon to the island of Barthelasse.

[d] Poivre: Voyage d'un philosophe, 1768. Bruce: Voyage en Abyssinie, t. V, p. 10 et seq.

The use of the plant was not confined to making paper. The root served for fuel. From the fibers of the stalk, dried and plaited, rope was manufactured. The roofs of houses were also covered with them. In case of famine the lower part of the stem was used for food, although its nutritive value is very slight. The stems, cut and joined together, served to make light rafts.[a]

The coarsest part of the papyrus was employed to make sails for boats or a material which the poor used for clothing.

The most ancient Egyptian texts on papyrus extant date back to 3580–3536 before our era.[b] Theophrastus speaks of it in his treatise on plants. Pliny copied this in part, but not altogether faithfully. The work of Pliny, however, possesses merit in a different direction. It is to him we owe the description of the manufacture of paper. Numerous writers have taken up Pliny's text, translating it, interpreting it, and even trying to manufacture paper.[c] Stodhart alone seemed to have been succeeding in his attempt, when, unfortunately, death interrupted his researches.[d] A bit of papyrus of his manufacture is preserved in the library of the French Institute. Dureau de la Malle published a long memoir on this manufacture.[e] He complains of the obscurity of Pliny's text, in which opinion he is confirmed by Paoli.[f]

The following seems to have been the method in manufacturing paper from papyrus:

The stalk, shortened at the top and base, was split by a sharp point through its entire length into very fine strips. This operation was generally begun in the center, and the first two central strips were reserved for the manufacture of paper of a superior quality. The succeeding layers were reserved for the manufacture of paper of an inferior quality. The two outside strips, composed almost exclusively of bark, had to be rejected. There is no question, as some writers have suggested, of the use of the bark; it was much too thin, composed, like most of the monocotyledons, of cells of compact tissue, filled with chlorophyl and perhaps with some traces of silica.

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[a] Were they rafts or boats? We can not determine from the texts. Even to-day the shore dwellers on the White Nile, the Chillouks, construct a species of raft from a reed called ambatch. (Schweinfurth: Tour du monde, 1874, pp. 287–288.)

[b] Hasting, op. cit., Vol. IV, p. 944.

[c] We may mention Guilandinus, Scaliger, Caylus, de Montfaucon, de Jussieu, Bruce, Cyrillo, etc.

[d] Saverio Landolina Nava could only succeed in obtaining, in the eighteenth century, a brittle paper. Stodhart made his researches in 1834.

[e] Mémoire sur la fabrication du papier chez les anciens. (Acad. des Inscr. et B. L. Mem. t. XXIX, 1851, p. 140 et seq.)

[f] Paoli (C.). Del papiro specialmente considerato come materia che ha servito alla scrittura. Firenze, 1878, 8°.

These slips (φιλυρη, philyræ) were laid together side by side upon an inclined table, whose surface was plentifully moistened, so that the slips adhered to each other. According to Pliny, they were dampened with Nile water, which alone could dilute the viscous liquid of the crushed cells, necessary to cause the lamellæ to adhere to each other.[a]

The layer formed by these slips was termed "scheda." On top of the scheda a new layer of slips was placed, crossing those of the lower one; thus a sheet, or plagula, was produced whose diameter in each direction was equal to the length of a philyra. When it was sufficiently desiccated, the plagula was squeezed in a press, which contracted every part of it; then it was exposed to the sun to dry.

A number of plagulæ, from 10 to 20, according to the period, were joined together, then they were rolled, and a quire, or scapus, was formed of it.

The quality of the papyrus obtained varied according to the width of the first cuts or philyræ. The best quality was called hieratic, later Augustine. Subsequently there was the Livian, the amphitheatric, the Fannian, of a most remarkable quality, the Saitic, the Tanitic, then the emporetic or commercial paper.

FIG. 28. Fragment of Troano paper manuscript. (De Bourbourg's Manuscript Troano. Paris, 1869.)

The paper obtained in Egypt was unfit to receive writing. It was subjected to further processes, beating and polishing, which imparted all the attributes required. In Rome certain slaves were charged with that work.

PAPER, PROPERLY SO CALLED.

The discovery of paper assured to the "book" an indefinite vitality and expansion. The material par excellence had, in fact, been found, indestructible material, which allows the book to be more pliable, less heavy, to pass down the ages as well, if not better, than papyrus and parchment.

It is to Tsaï Loun, minister of agriculture in China, one hundred

[a] The mere viscosity of the crushed cells should have sufficed to make the contiguous slips adhere to each other; and, if water was necessary, was it indispensable to have the water of the Nile?

and twenty-three years before our era, that the invention of paper is due. Whether it was in consequence of cordial relations or through Chinese prisoners that paper was introduced in Samarcand is of little importance; the fact is certain that it did become known there in 751. Forty-three years later paper was known at Bagdad and at Damascus. Its employment and manufacture spread rapidly in Syria, Arabia, Egypt.

Doctor Karabacek had the good fortune to recover, among the treasures of El Uschmunein, all the secrets of Egyptian paper makers.[a] He even discovered bills, or receipts of imposts, dating from 950 to 1036 of our era. This paper, is sometimes very thin and often highly glazed.

In the twelfth century paper mills were established in Fez, Morocco, and in Xativa, Spain, whence they spread to Valencia and other cities.

In Italy paper mills existed at Fabriano from the thirteenth century. The collection of Prof. A. Zonghi comprises several thousand samples of paper from that locality, dating from 1267 to 1750. He even had the patience to raise the filigrees from these papers, and his manuscript album contains more than 20,000 designs.[b] According to a charter of the bishop of Lodève, granted in 1189 to Raymond de Popian, a paper mill was to be erected at that date in Hèrault, but this document could not be found. It is only cited in the chronology of the bishops of Lodève. Some reservation must therefore be made.

This is not the case with another document found in the cartulary of the monasteries of Gellone and Aniane, published by Meynial and the Abbé Cassan. It is beyond doubt, according to this record, that paper was known in France in 1346.[c]

Its introduction into Europe seems to coincide with the exodus of the Jews to Spain and the south of France after the Arabs had expelled them first from the north of Africa and later from the south of Spain.

Paper must have been introduced into Germany in the second half

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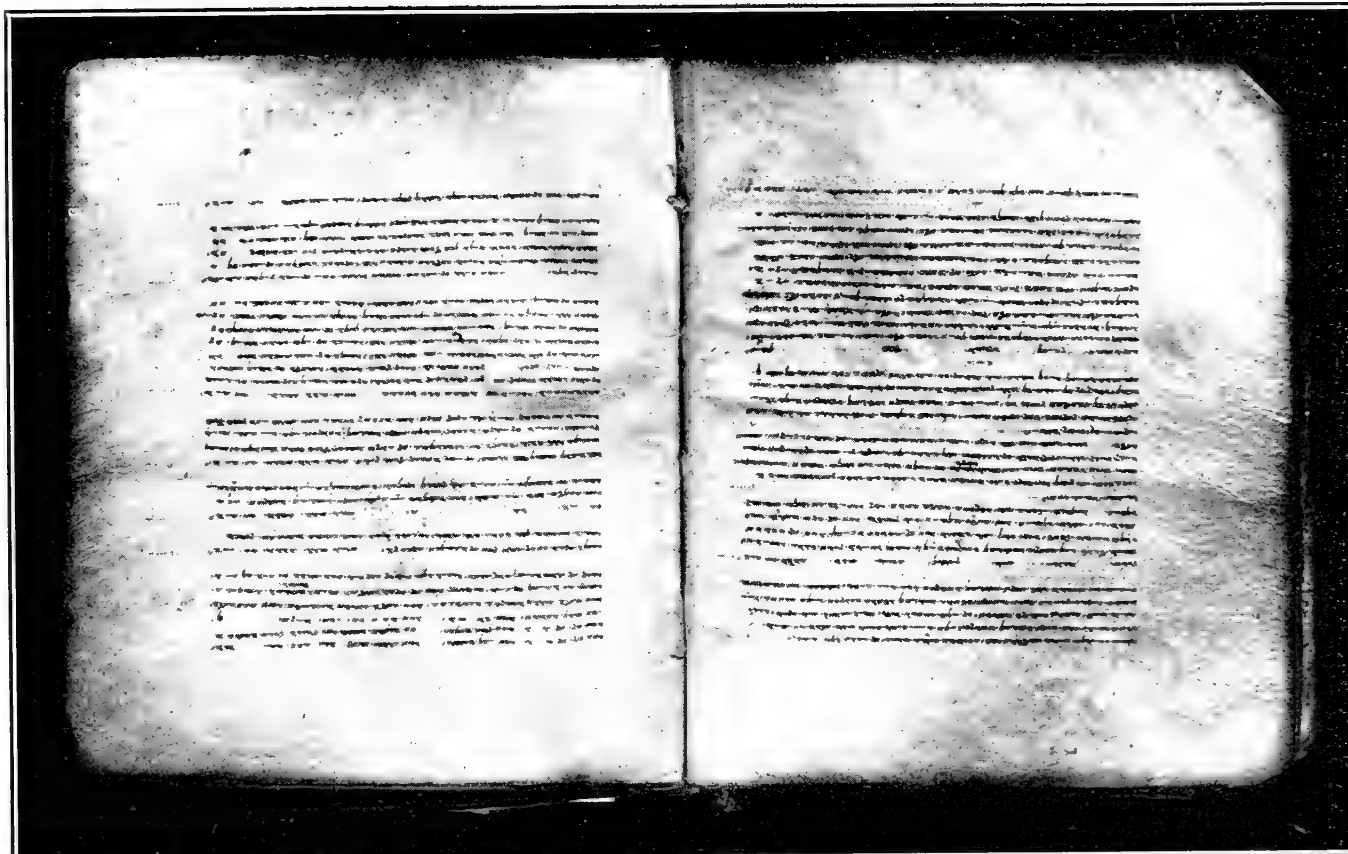
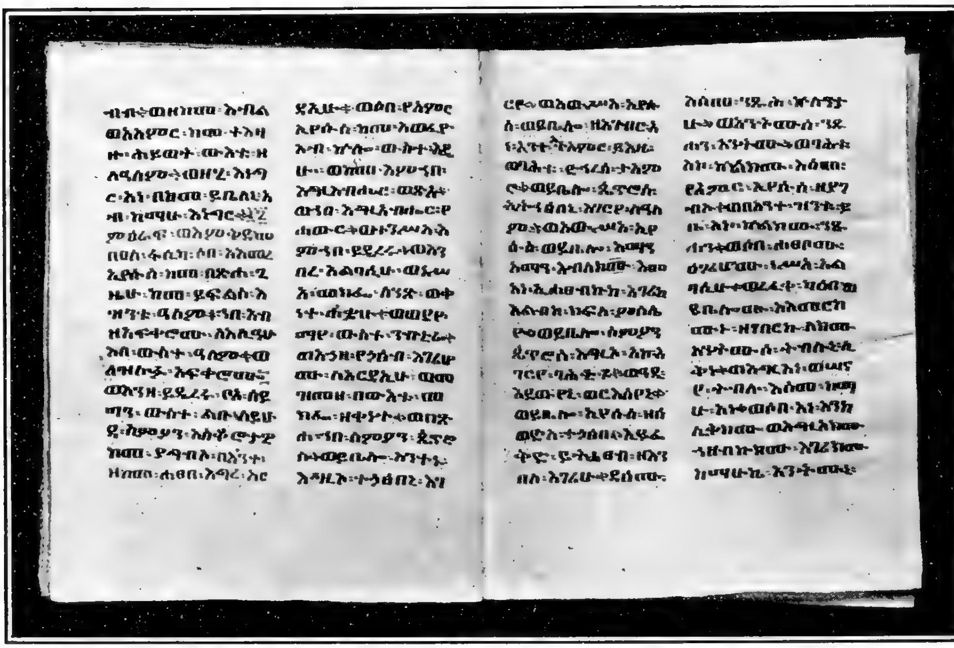
[a] Doctor Karabacek. Das arabische Papier. Eine historische-antiquarische Untersuchung. Wien, 1887, gr. 40.

[b] Musée rétrospectif de la classe 88. Fabrication du papier (Matières prèmieres, materiel, procédés et produits) à l'Exposition universelle internationale de 1900, à Paris. Rapport de la Commission, d'Installation. Saint-Cloud, s. d., gr. 8°, p. 15–17.

[c] " L'abbé de Saint-Guilhem donne à nouveau cens à Paul Gilles, marchand de Montpellier, originaire de Saint-Guilhem, le tènement de Rieux Cabrie " quod extenditur a quodam loco vocato los estregs des cols de Cazelas, usque ad pontem vocatum Manafossa * * * in quo quidem tenemento consensiit dominus Abbas quod idem Paulus et sui successores possint et valeant facere et reficere molendinum et molendina, paratorum et paratoria, bladerum et bladeria, papireum et papirea, et alia quæcumque." (Cité dans Musée rétrospectif * * *, p. 12.)



Hebrew Manuscript of the Pentateuch in Samaritan Characters, on Vellum.



ETHIOPIC MANUSCRIPT OF THE GOSPEL OF JOHN, WRITTEN ON PARCHMENT.

of the fourteenth century. Ulmann Strœmer had established himself at Ulm. Born in 1328, he died in 1407. He has left memoirs in which he recounts his annoyances with some of his workmen.[a]

Mentel, a contemporary of Gutenberg (1400–1478), established a paper factory at Strasburg.

John Tate is the first paper maker in England. After him must be mentioned Spielmann, of German origin, jeweler to Queen Elizabeth. He was created a knight and obtained for a term of ten years the exclusive privilege of collecting all the rags required for his mill.[b]

In the beginning, paper was manufactured in a mold—that is to say, the workmen drew directly from the vat of paste a certain quantity of it, and, by a particular twist of the hand, he spread it over a frame, whose under side was formed of brass wires (wire cloth) stretched, and pressed against each other, and kept rigid by other metallic threads (cross rods) somewhat stronger, and placed across the first. The whole process of manufacturing paper is too familiar to require anything further to be said regarding it.

Until recently the opinion of scholars and of all those who had studied the composition and the manufacture of paper was that the first products of that industry were made from cotton. The name itself under which paper was designated in Latin and Greek seemed to demonstrate this: Charta bombycina, cuttunea, damascena, χἀευης 6ομ6ἀχινος.

Numerous dissertations, erudite enough, but all equally inaccurate, attempted to prove the existence of cotton paper.[c] All the proofs in favor of this method, based solely on the outside and superficial appearance of the paper, and on the texts containing vague definitions, vanished as soon as a really scientific analysis and examination of paper was made. Wiesner and Briquet were the first to examine paper with the microscope; the latter has recorded in the Mémoires de la Société des Antiquaries de France (5e série, Tome VIe, 1885) the result of a microscopic analysis of 122 specimens of paper from the most varied sources, and embracing a period extending from the eleventh to the fifteenth century.

The following is the résumé of his conclusions:

There has never been any cotton paper.

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[a] Musée rétrospectif, Class 88, pp. 18–19.

[b] Ibid., p. 22.

[c] Montfaucon. Dissertation sur le papyrus, sur le papier de coton et sur celui dont on se sert aujourd'hui. Mém. de littérat. tirez des Registres de l'Académie royale des Inscriptions et belles-lettres depuis 1718 à 1725. Paris 1729, t. VI, p. 591.—Wattenbach. Das Schriftwesen in Mittelalter. Leipzig, 1871.—Sickel. Historische Zeitschrift, t. XXVII, p. 442.—Wailly (Nat de). Eléments de paléographie, etc.

Rag paper is more ancient than has been supposed. It goes back to the tenth century.

Rag paper was first used in the Orient. It did not penetrate into the Occident until two or three centuries later.

Paper was filigreed from the thirteenth century in the Occident. This practice was transported later to the Orient.[a]

It is certain that in China from the very origin of the discovery of paper, bamboo must have been used in its manufacture. Other vegetable materials may have contributed to the same use. The Japanese paper which we know is manufactured from the bark of certain small trees, Edgewortia papyrifera, Broussonetia papyrifera, and Wikstrœmia canescens.

A longer digression upon this subject would carry us beyond our projected limits. With the discovery of printing we must stop.

We may conclude by saying that man, inspired by the desire of leaving traces of his life and actions, sought every means to transmit them to his descendants. What an evolution he has passed through from the pictographic inscriptions upon the rocks to the phonetic alphabet written on paper and finally printed.

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[a] Briquet (C. M.) Recherches sur les premiers papiers émployes en Occident et en Orient, du X^{e} au XV^{e} siècle, pp. 133–180. Followed by Analyses microscopiques de papiers du moyen âge, pp. 181–205, 1 plate outside the text.

AN INQUIRY INTO THE POPULATION OF CHINA.[a]

By William Woodville Rockhill.

I.

From the earliest times of their history the Chinese have made every few years enumerations of the adult population of the Empire. The history of the census in China may be divided into two parts. During the first, extending from the first recorded count in the twenty-third century B. C. down to 1712 A D., with a few exceptions, the number of tax-paying households alone was recorded. In the second period the total number of individuals is purposed to have been taken.

In the first period the census was made solely for the purpose of levying the taxes, and there is every reason to believe that the local officials systematically kept the returns forward to the central Government below the real figures, so as to divert to their own use as much of the taxes levied as they possibly could. In the second period, that reason no longer existing (see infra, p. 663), it became a matter of pride with the officials, as well as good policy, to swell the returns of population.

There is much uncertainty as to the number of individuals contained in each recorded "household" or hu, and whether by the word "individual" (literally "mouth," k'ou) is to be understood male adults, or both sexes, or persons of all ages—exclusive of infants—who have never been included in the enumerations of any period. In the time of Mencius (fourth century B. C.) the "family" (chia) was supposed to comprise eight months (k'ou). This was the number of persons whom 100 mou (about 15 acres) of medium land were computed to support.[b] Under some dynasties (as the Han) it would

[a] Reprinted from Smithsonian Miscellaneous Collection (Quarterly Issue) vol. 47. December 10, 1904.

[b] Mencius, bk. I, pt. I, Ch. VII, 24.

seem that the "household" comprised from 4.8 to 5.2 individuals; in others, the T'ang, for example, it rose to 5.8. During others, as the Sung, it was only a fraction over 2 persons, according to Sacharoff,[a] though Biot[b] contends that in this period it was a fraction more than 5 persons, as in the preceding period of the T'ang. Under the Yuan dynasty, according to Amiot, the "household" comprised 5 persons, and in the succeeding Ming dynasty it seems to have varied from about 5 to over 6.6. Even during the present dynasty we are in grave doubt as to the numeric value of the term hu ("household," "family"). Father Amiot and other foreign writers have thought it represented 5 persons, de Guignes[c] says 2 to 3, but in the opinion of E. H. Parker it averaged 6 persons.[d] In the census of 1842, which gave the number of households and of individuals, the former averaged 2.3 persons to the family; and in a census of the city of Peking for 1846 it averaged 3.1. I am disposed to accept 4 as a fair figure for enumerations of the eighteenth and nineteenth centuries.[e]

During the Han dynasty, from A. D. 1 to 156, we have 10 enumerations.[f] The first, taken in A. D. 1, gave 12,233,062 "households" and 59,594,978 "individuals." The last, taken in 156, gave 16,070,906 "households" and only 50,066,856 "individuals." The territory over which these censuses extended did not vary appreciably during the whole of this period of one hundred and fifty-five years; it was substantially the same as at the present day. The population during this century and a half was nearly stationary.

In A. D. 606, when China was again united under one rule, what has been held by western writers to be a very careful census was taken. It again gave the population of the Empire at about 55,500,000.[g]

During the seventh, eighth, and ninth centuries, although a considerable number of enumerations of the people are recorded, they are so confused that it is impossible to fix with more than the roughest approximation the population at that time of China proper, which

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[a] Hist. Uebersicht der Bevölkerungs-Verhaltnisse China's, p. 157.

[b] Journal Asiatique, 1836, t. I.

[c] Voyage à Peking, III, 69.

[d] See infra, pp. 663–664. In Japan the average number of persons by household, which often includes several families, was 5.55 at the close of 1898.

[e] It is true that in the case of the prefecture of Wen-chou, in Che-kiang, it was found in 1881 that the average number of persons per home was about 5.14 (see infra, p. 314), and in the case of Ch'ung-k'ing in Ssŭ-ch'uan in 1877 a detailed census of the city gave about 4.3 persons to a family (E. C. Baber, Journ. of Explor. in west. China, p. 25).

[f] Ma Tuan-lin, Wen-hsien t'ung-k'ao, bk. 10.

[g] See Biot, op. cit., pp. 451–452.

then covered about the same area as at present. The census which appears to have been the most carefully made was that of the year 756. It gave 8,814,708 families and 52,919,309 individuals for the free population, exclusive of infants and very old people; it included the kingdom of Korea. The total population in A. D. 756 may therefore have been about 61,000,000. Biot, using the censuses referred to in this paragraph, has calculated the average yearly increase of the population of Chian proper between A. D. 650 and 755, and found it to have been about 0.0063 per cent.

During the eleventh century, when the Empire was again united under the rule of the Sung, we have ten enumerations of the population, that of the year 1080 showing evidence of having been the most carefully taken. It gives the number of households of freeholders (chu) and tenants (k'o) as 14,852,686, or 33,303,889 individuals. No matter how numerous we allow the exempted and unenumerated classes to have been, it is not conceivable that they could have more than doubled this number; so we may, I think, safely assume that at the end of the eleventh century the population of China proper was not much more than 60,000,000, the same as in the middle of the eighth century.

Biot has calculated the average yearly increase during the Sung dynasty (A. D. 976 to 1102) and found that from 976 to 1021 it was about 0.02 per cent, and from 1021 to 1102 only 0.0103 per cent, or 0.015 per cent during these one hundred and twenty-five years.

In 1290, at the end of the Mongol conquest of China by Kublai Khan, a census of China proper gave 13,196,206 households of 58,834,711 individuals. Admitting that vast numbers of Chinese had been reduced to slavery by the Mongols and countless thousands had been killed, the population at the end of the thirteenth century can hardly have been much in excess of 75,000,000.

During the Ming dynasty there were no fewer than 21 censuses between 1381 and 1578. The highest figure of the recorded population during this period was 66,598,337 individuals in 1403, and the lowest 46,802,005 in 1506. The last census, that of 1578, taken at a time when the country was extremely prosperous and enjoying general peace, gave the population as 63,599,541 souls.

While agreeing with Sacharoff that the various censuses of this period are not of a trustworthy character, I believe they may be considered sufficiently accurate to show that during the fifteenth and sixteenth centuries the population of China increased very slowly, certainly not more rapidly than during previous periods of its history.

The following returns of the detailed censuses of 1393, 1491, and 1578 are taken from the Annals of the Ming.[a] It must be noted that that of 1393 has no returns for several provinces of the Empire.[b]

	1393.		1491.		1578.	
	Households.	Individuals.	Households.	Individuals.	Households.	Individuals.
Ssŭ-ch'uan	215,719	1,466,778	253,803	2,598,460	262,694	3,102,073
Kiang-hsi	1,553,923	8,982,482	1,363,629	6,549,800	1,341,005	5,859,026
Hu-kuang	775,851	4,702,660	504,870	3,781,714	541,310	4,398,785
Che-kiang	1,138,225	10,487,567	1,503,124	5,305,843	1,542,408	5,153,005
Fu-kien	815,527	3,916,806	506,039	3,106,060	515,307	1,738,709
Kuang-tung	675,599	3,007,932	467,390	1,817,384	530,712	5,040,655
Kuang-hsi	211,263	1,482,671	459,640	1,676,274	218,712	1,186,179
Shan-tung	753,894	5,255,876	770,555	6,759,675	1,372,206	5,664,099
Shan-hsi	595,444	4,072,127	575,249	4,360,476	596,097	5,319,359
Ho-nan	315,617	1,912,542	575,249	4,360,476	633,067	5,193,606
Shen-hsi	294,526	2,316,569	306,644	3,912,370	394,423	4,502,067
Yün-nan	59,576	259,270	15,950	125,955	135,560	1,476,692
Kuei-chou			43,367	258,693	43,405	290,972
Ching-shih			304,055	3,448,977	334,691	4,258,453
Nan-ching	1,912,914	10,755,948	1,511,853	7,993,519	2,069,067	10,415,861
Total	9,318,078	58,619,228	9,161,417	56,055,676	10,530,664	63,599,541

Between the founding of the present Manchu dynasty (A. D. 1644) and 1734 we have enumerations of the population by households for nearly every year. E. H. Parker has extracted them from the Tung hua lu for the years between 1651 and 1860.[c] From 1651 to 1730 they are as follows for every tenth year:

[a] Ming Shih, Bks. 40 and 43.

[b] It is interesting to note that nearly all European writers of the latter part of the sixteenth and of the seventeenth centuries, such as Trigault, Matteo Ricci, Herrada, Martin Martini, Semedo, Mandelslo, and Osbeck, give approximately the figure of the census of 1578 as that of the population of China in their time, some of them stating that it included only adult males or "fighting men." I can find no authority for this in any Chinese work. Gemelli Careri (Voy. Round the World, Pt. IV, 326) made out the population of China at the end of the seventeenth century to be 59,788,364 men, "exclusive of women, children, paupers, officials, literati, army, the imperial clan, etc." He gives the number of families as 11,502,872. The figures, both of individuals and of households, are substantially those of the census of 1578. He cites no authority for his statement concerning classes of the population not included in the census. I am inclined to believe he took his figures and this statement bodily from Athanasius Kircher or Father Martin Martini, but they in turn furnish no authority for their belief that the recorded population was exclusively composed of male adults.

[c] E. H. Parker, A Note on Some Statistics Regarding China, Journal Royal Statistical Society, XII, pt. 1, pp. 150–156. Du Halde, Description, etc., II, p. 14, referring to the early enumerations of the present dynasty, states that the taxpayers were the adult males only between twenty and sixty years of age.

	Families.
1651, taxed population	10,633,000
1660, taxed population	19,088,000
1670, taxed population	19,396,000
1680, taxed population	17,095,000
1690, taxed population	20,364,000
1700, taxed population	20,411,000
1710, taxed population	23,311,000
1720, taxed population	24,720,000
1730, taxed population	25,480,000

In the case of the census of 1720 we are told that there were, exclusive of the taxed population, 309,545 families free from taxation, and 851,959 families in the case of that of 1730. Parker notes that "evidence clearly shows" (but, as usual with him, he does not go to the trouble of giving any) "that the numbers given above must be multiplied by six, and not by five, as was done by Amiot, in order to obtain the number of individuals." Pending production of evidence, I shall follow Father Amiot's views on this point, and would add 2 per cent for the tax-free families, which include officials, literati, the army, etc. On this basis we find that the total population of China proper in 1651, during the troublous times which accompanied the establishment of Manchu supremacy, was about 55,000,000—just about the number we should have assumed it to be had we to deduct it from the data supplied by history alone. From 1651 down to the present time the figures of the returns vary with such extraordinary rapidity, so unlike anything we have noted in the whole long list of earlier Chinese enumerations, that one is inevitably brought to look on them as fanciful and probably far remote from the truth.[a]

In 1712 an imperial edict ordered that the number of families (24,621,334) given in the enumeration of the preceding year should remain the invariable basis for the assessment of the crown taxes, and that all subsequent censuses should give the total number of inhabitants. Nevertheless, it was only in 1741, after repeated orders had been given by the Imperial Government, that a return was made of the total population of China. According to it the population was 143,412,000. For 1743 we find in the Institutes of the Ta Ch'ing dynasty (Ta Ch'ing Hui-tien) a detailed census of the seventeen provinces—corresponding to the eighteen of the present day—but again given by households. This census gave the total number of households (hu) as 28,877,364, comprising 143,621,460 individuals, or about 4.8 persons to a household. To this number, which

[a] De Guignes (Voyage à Peking, Vol. III, pp. 56–86), after a study of the Chinese census returns of 1743, 1761, and 1794, concluded that they were exaggerated, and also that the figure five adopted by the missionaries to ascertain the number of persons in a family was too high by half. He calculated the population of China proper in 1789 at 150,000,000 as a maximum.

corresponds very closely with that given for 1741, Amiot would add 493,075 individuals for unenumerated officials, 2,470,000 for the literati, and 4,115,325 for the army. To this again he would add some 50,000,000 for the civil employees of Government, the monks, nuns, brigands, vagabonds, troglodytes, etc., with which, he says, China is full. Here I think he is unquestionably wrong, for the civil employees were included either in the already accounted for class of officials, or in the general returns,[a] while as for monks, nuns, etc., the number was unquestionably so small that it may be omitted in such a rough estimate as that we are attempting to reach. We may adopt the number 143,000,000 individuals as a maxmum for the total population of China proper in 1743.

The various estimates of the population made by the Government of China since 1743 are contained in the following table, in which have also been included the annual rates of increase or decrease between succeeding dates deducted from them:

[Minus mark (—) indicates decrease.]

Date.	Population.	Annual increase.	Rate of increase.
1743	150,700,000		
1749	177,089,000	4,398,167	2.90
1757	189,920,000	1,601,375	.90
1761	200,339,000	2,604,750	1.37
1767	209,126,000	1,464,500	.73
1771	213,897,000	1,192,750	.57
1776	267,399,000	10,700,400	5.00
1780	276,632,000	2,308,250	.86
1783	283,094,000	6,462,000	2.34
1812	360,444,000	2,667,241	.94
1842	413,021,000	1,759,233	.49
1850[a]	414,493,000	159,000	.038
1860	260,925,000	—15,356,800	—3.705
1882	381,309,000	5,472,000	2.097
1885[a]	377,636,000	— 1,224,333	— .32

[a] The figures for 1850 and 1860 are given on the authority of the Tung hua lu. The data from which the figure for 1885 is deduced were supplied me in 1885 by the Chinese board of revenue Hu Pu, and supplemented and completed by figures supplied by the same board to Mr. Popoff for ten provinces for the year 1879. This enumeration, as also those for 1761, 1812, 1842, and 1882 are given in detail, infra, p. 676. See also S. Wells Williams, The Middle Kingdom, I, 258.

Since the last date in the preceding table a number of estimates of the population of China proper have been made by various writers, but none of the estimates has any particular value, all of them being based on the data supplied Popoff for 1879 and 1882. E. H. Parker [b] gives from Russian sources the population of the various prov-

[a] Ta Ch'ing Lü-li, 3d Div., Bk. I, Sec. LXXVI, provides for the registration of persons in the civil and military services.

[b] China, etc., 192.

inces for 1894; this is the wildest guess yet made, and foots up a total of 421,800,000. In 1903 the Statesman's Year Book (p. 506) published a table "issued by the Chinese Government as the results of a census taken for the purpose of the apportionment of the indemnity to the powers," in which the population is estimated at 407,253,000. There is not a scintilla of evidence to show that any census was taken for the purpose stated, and, furthermore, there was no necessity for taking one, as the sums levied from the various provinces for the indemnity of 1900 were procured by indirect taxation. Here again we have nothing more than a guess of the Chinese board of revenue.

II.

An attempt will now be made to determine the value of the various enumerations of population since that of 1741, which I am inclined to believe was probably a closer approximation to the truth than were any subsequent ones, the Imperial Government being in strong, intelligent hands, its mandates executed with more faithfulness and precision than at any other subsequent period, and the Empire enjoying perfect peace. I feel confident, however, that it was in excess of the truth, for it must be borne in mind that no census such as we make in this country has ever been attempted in China. The statutes of the Empire[a] require, it is true, that all families should make returns of their members, and impose punishments for failure to comply or for falsification of returns; it would therefore seem easy to tabulate these returns at any time, but experience has proved that such is not the case. In China all statements of population are largely guesswork, and where numbers are guessed they are always magnified, especially when there is no reason to keep them down, as was the case prior to the imperial edict of 1712, referred to previously.

China enjoys a salubrious climate and a fertile soil, and the people have always been extraordinarly industrious and thrifty. As a general rule the taxation has been fairly equable, and life and property safe in times of peace. These conditions are all conducive to a large increase in population. There is another reason which should from the remotest times have been potent in producing a larger increase of population in China than in other countries enjoying like natural advantages. I refer to the desire of every Chinese to have posterity to keep up the ancestral worship. We find Mencius (B. C. 372–289) saying: "There are three unfilial acts, and to have no posterity is the greatest of them" (pu hsiao yu san, wu hou wei ta).[b]

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[a] Ta Ch'ing, Lü-li, 3d Div., Bk. I, Secs. LXXV, LXXVI.

[b] Mencius, Bk. IV, Pt. I, Ch. XXVI.

Failure to support one's parents enduring poverty is only second to it, for by failing to have posterity one offends against the whole line of one's ancestors by putting an end to the sacrifices due them. To this belief is due the universal practice of early marriages which has always prevailed in China.

The exceptional checks we find to a large increase of the population are, however, quite as potent as the encouragements to its increase just mentioned. Among these, famine, floods, and pestilence have been the most constantly operating, and have arrested rapid increase more even than the losses incurred through the fearful butcheries which have throughout China's history invariably accompanied the suppression of every rebellion, the establishment of every new dynasty.

Alexander Hosie in his paper on "Droughts in China from A. D. 620 to 1643,"[a] or during a period of one thousand and twenty-three years, found that drought had occured in five hundred and eighty-three years in some one of the eighteen provinces, frequently in four or five of them at the same time, and in many cases they were accom-

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[a] Hosie's inquiries, drawn from the great Chinese work called the T'u-shu chi ch'eng (see Journ. Ch. Br. Roy. Asiat. Soc., n. s., XII, 51 et seq.), may be summarized as follows:

Between A. D. 620 and 700 inclusive, there were 41 years with droughts, of which 2 were the results of great floods.

From 701 to 800, inclusive, there were 46 years with drought. In 790 typhus ranged.

From 801 to 900, inclusive, there were 43 years with drought, 8 of which were of great severity.

From 901 to 1000, inclusive, there were 60 years with drought, 13 being "great droughts."

From 1001 to 1100, inclusive, there were 68 years with drought, 6 being of long duration, 8 "great droughts" and one (1086–87) universal and of long duration.

From 1101 to 1200, inclusive, there are 60 recorded droughts, of which 9 were "great droughts," 4 of long duration and 5 "very severe."

From 1201 to 1300, inclusive, there were 76 droughts, of which 12 were "great droughts" and 4 "very severe."

From 1301 to 1400, inclusive, there were 59 years with drought, of which 25 were "great droughts," 4 accompanied with floods in other sections of the country, 4 with locusts, and during 6 of the droughts the people resorted to cannibalism.

From 1401 to 1500, inclusive, there were 57 years with drought, of which 36 were "great droughts;" during 8 cannibalism is recorded, and during several typhus raged.

From 1501 to 1600 there were 84 years with drought, of which 69 were "great droughts" (in A. D. 1568 it extended over 8 provinces); during several cannibalism is recorded.

From 1601 to 1643, there were 15 years with drought. In 15 years it occurred in Shan-hsi and in 11 in Che-kiang.

panied by floods, typhus, and other scourges. Frequently these droughts lasted in the same section of country for several successive years or occurred at such close intervals that the country had not time to recover from them. To cite but two cases: from A. D. 1601 to 1643 drought is recorded in some one province of China in thirty years, in fifteen of which it occurred in the province of Shan-hsi, and in eleven in that of Che-kiang.

The fearful loss of life which has marked every calamity that has visited any part of China, and the nearly incredible cruelty which has been shown in the suppression of every uprising that has taken place from the earliest days down to the present time, are unfortunately too well authenticated to be denied.

Without going back to the early annals of the Chinese for examples of the terrible mortality which has always attended natural calamities and warfare in China, a few in the last three centuries, vouched for by reliable European writers, or by foreigners resident in the country at the time of their occurrence, may be cited here.

Father Du Halde[a] states that in the year 1582 "there was such a great drought in the Province of Shan-hsi, that it was impossible to count the number of those who died of starvation. There were dug in various localities some sixty great ditches, each of which held a thousand corpses, and were thereafter called Van gin keng." (Wan jen k'êng), "Grave of a myriad men."

The same author[b] says that on September 2, 1678, there was an earthquake in the Province of Chih-li when over 30,000 persons lost their lives in the town of T'ung-chou alone. On November 30, 1731, there was another earthquake in the same province, when over 100,000 persons lost their lives in Peking, and more than that number in the adjacent country.

Father Amiot,[c] writing from Peking, May 20, 1786, tells of a terrible drought which for the three past years had visited the provinces of Kiang-nan, Ho-nan, and Shan-tung. The people in vast numbers sought to reach other provinces, but thousands upon thousands died on the roads and their corpses were devoured by the survivors.

As regards the extraordinary loss of life attending military operations in China, Du Halde states[d] that in 1635 the Chinese, to defend the city of K'ai-feng Fu in Ho-nan against the rebels, cut the Yellow River dikes. The whole city was submerged and 300,000 persons lost their lives.

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[a] Description, I, p. 522. The expression Wan jen k'êng is colloquially used to designate a pit into which the bodies of executed criminals are thrown. See H. A. Giles, Chin. Dict., s. v., k'êng.

[b] Ibid. I, p. 543.

[c] Mém concernant les Chinois, XIII, p. 425.

[d] Op. cit., I, p. 530.

The history of Ch'ang Hsien-chung, told by Du Halde,[a] by Father d'Orelans,[b] by Father de Mailla,[c] and others, is an example of what has frequently occurred in China during its long history. In the disturbed period which followed the overthrow of the Ming dynasty this person overran with his troops the provinces of Ho-nan, Kiang-nan, Kiang-hsi, and Ssŭ-ch'uan. It is said that for the slightest offense not only was the offender himself put to death, but the same punishment was visited on all the inhabitants of the same street. Five thousand eunuchs were beheaded because one of their number refused to treat him as Emperor. He called some 10,000 students to the examinations at Ch'êng-tu Fu in Ssŭ-ch'uan and had them all put to death. He had butchered over 600,000 persons in that province alone! On leaving Ch'êng-tu to march into the adjoining province of Shen-hsi he had all the inhabitants chained, led out of the city, and executed. Then he ordered his soldiers to put to death their own wives as troublesome impediments in times of war, and he gave the example by having his own wives executed. So reads his story. If it is not all true much of it certainly is.

Turning to the nineteenth century, always on the authority of careful European investigators, Colonel Kuropatkin (the present commander in chief of the Russian army in Manchuria) speaking[d] of the Mohammedan rebellion in Shen-hsi and Kan-su of 1861 and subsequent years, states, on the authority of Sosnovski, that on the occasion of the siege of Ho-chou in Kan-su, which lasted seven months, 20,000 men were put to death by the Chinese on the fall of that place. When the neighboring town of Hsi-ning Fu was captured, 9,000 were put to death. At the capture of Chin-chi P'u, the Mohammedan stronghold, 50,000 were killed and a vast fruitful and thickly populated tract turned into waste. At Chuguchak and its environs 40,000 men perished at the hands of the Chinese, and the town was left without a single inhabitant.

Doctor Macgowan, who was residing in China during the whole of the T'ai-p'ing rebellion, says of it:[e] "Nine provinces had been desolated by it; flourishing towns and cities had been made heaps of ruins, and wild beasts made their dens within them, whilst fully thirty millions of people had been put to death by these ruthless robbers" (rebels and imperialists).

Another authority says: "During the first year of the great Tai-ping rebellion the registered population declined by two-fifths, but

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[a] Description, I, p. 535.

[b] History of the Two Tartar Conquerors of China, Hakluyt Society edit., p. 26.

[c] Hist. Gén. de la Chine, X, 470–479; XI, 17–28.

[d] Kashgaria, English trans., p. 155.

[e] History of China, p. 575. Conf. S. Wells Wiliams, The Middle Kingdom, II, 623.

though many millions must have perished, it is not at all likely that the numbers of 1850 (414,493,000) were more than decimated. Even then, to kill or starve 43,000,000 people in ten years would mean 12,000 a day, in addition to the 40,000 a day who (at the rate of 30 per thousand per annum) would die naturally, and would balance about the same number of births. Moreover, the rebellion covered only one-half the area of China, so that 24,000 a day is certainly nearer than 12,000.[a]

The loss of life attending the crushing of the two Mohammedan and the Nien-fei rebellions (1860–1875) mounted certainly to over a million. Then we have a quarter of a million killed in the suppression of the Mohammedan rebellion in Kan-su in 1894–95. If we add to this terrible source of loss of population that resulting from famines and floods, the total is nearly doubled. There were great famines in 1810, 1811, 1846, and 1849, which, according to the Tung hua lu, the best official authority we have on the subject, reduced the population by 45,000,000. Although this figure may seem excessive, we know that in the next great famine, that of 1877–78, which visited only four provinces of the Empire with great severity, no fewer than 9,500,000 persons fell its victims. This figure I quote on the authority of the China famine relief committee of Shanghai.

We must add to this again the loss of life which attended the great flood of 1888, when the Yellow River broke its banks and flooded nearly the whole province of Ho-nan. According to memorials sent at the time to the Emperor, about 2,000,000 were drowned or starved to death by this catastrophe. Then there is the unknown, but certainly terrible, mortality during the great drought and famine in Shan-hsi, Shen-hsi, Chih-li, and southern Mongolia in 1892–93 and 1894. There have also been numerous epidemics of cholera and plague which have devastated sections of the Empire in the last twenty to thirty years, and still we have not exhausted the list of causes of violent fluctuations, of extraordinary loss to the population of China during the nineteenth century.[b]

It must not be lost sight of that these figures represent only the mortality among adults; it is extremely improbable that infants were counted at all.

Popoff, in his study on the population in China,[c] estimates that the

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[a] E. H. Parker, China, p. 190.

[b] I was told in 1901 by the late Li Hung Chang that over 30,000 Chinese lost their lives in Peking alone during the Boxer troubles of 1900. Admitting that this figure and all those here given are exaggerated, it is true beyond all doubt that the loss to the population from these causes has been fearful.

[c] P. S. Popoff in Novoe Vremya, No. 3066, September 10, 1884. Conf. S. Wells Williams, The Middle Kingdom, I, 270.

population of China proper has not only not increased during the period of forty years, from 1842 to 1882, but has even diminished by the considerable number of 30,942,592.

The only reliable data I have found on the subject of Chinese vital statistics are the following:

In 1880 the governor of the province of Che-kiang reported[a] to the Emperor that as the result of a general census of the province taken in 1879 it was found that the population was 11,541,054.

Mr. Popoff, the interpreter of the Russian legation in China, was informed in 1882 by the board of revenue in Peking that the population of this same province of Che-kiang was then 11,588,692, and in 1885 the same board informed the writer of the present paper that it was then 11,684,348.

As corroborative evidence of the value of these figures, we learn that Commissioner of Customs Alfred E. Hippisley[b] found by a careful report made to him by the taotai of the prefecture of Wen-chou that the average number of persons per home was about 5.14, and that the total population of the prefecture was 1,841,690. "The area of the prefecture being about 4,500 square miles, the average population would therefore seem to be about 409 to the square mile in this prefecture, and thus largely in excess of the general average of the province."

The best available information concerning the area of the province of Che-kiang[c] gives it as 34,700 square miles. Assuming, then, that the average population to the square mile is one-fifth less than in the prefecture of Wen-chou (say 325 to the square mile), the total population of the province in 1881 would have been about 11,145,000—a figure substantially agreeing with that given by the governor of the province for 1879 and that supplied Popoff in 1882.

The population of Che-kiang, according to the above figures, increased from 1879 to 1882—say about three years (1880–1) from 11,541,054 to 11,588,692, or 47,638. From 1882 to 1885 (also three years) it increased from 11,588,692 to 11,684,348, or 95,656. This would be an annual increase from 1879 to 1882 of 0.206 per cent, and from 1882 to 1885 of 0.275 per cent, or an average yearly rate from 1879 to 1885 of 0.240 per cent—this under the most favorable possible circumstances, the country being blessed with peace and plenty during all that period and for some years previously. At this

[a] Peking Gazette, March 17, 1880.

[b] Trade Report of Wen-chou for 1881, pp. 27–28.

[c] Statesman's Yearbook, 1902, p. 495. It may be said that the returns for Che-kiang show just the contrary of what I am seeking to prove, but it must be seen at once how fanciful must be the returns of population when the total number in a vast province is deduced from a rough count in a small district. This is substantially the method the Chinese follow.

rate the population of Che-kiang would double itself by natural increase in 417 years.

Newsholme,[a] calculating the average birth rate and death rate for the five years 1891–1895, found that in Prussia the population would double itself by natural increase in 49.2 years; in England in 59.1 years; in Italy in 65.7 years; in Austria in 74.1 years, and in France in 591 years, the annual increase in the period named averaging in the latter country only 0.08 per 1,000. Conditions of life in other provinces of the Empire of China are approximately the same as in Che-kiang—in fact, in a number they are worse, particularly as regards the frequency of famines, floods, and epidemics; nevertheless, Chinese enumerations would have us believe that the population in China increases more rapidly than in the most favored countries of the world.

In the case of China, natural increase is the only one to be taken in line of count; immigration into China is practically nil, and emigration from China proper to other portions of the Empire, excluding Asia, has only within quite recent times become of considerable size, and even now it is not sufficient to appreciably affect the sum total of the population in the approximate count we are trying to make of it. The only migratory movements of the Chinese have been from province to province of the Empire. Without going far back into the past it will suffice to mention the repopulation of the provinces of Ssŭ-ch'uan and Yün-nan after the Manchu conquest from the Hu Kuang provinces and the similar movement to Ssŭ-ch'uan during the great T'ai-p'ing rebellion. The emigration from Shan-hsi into southern and eastern Mongolia after the famine of 1877–78, and that from Shan-tung and Chih-li into Manchuria still going on, are the most important recent movements of population to outlying parts of the Chinese Empire. The emigration to southern Asia and to remoter parts of the world is drawn exclusively from the provinces of Fu-kien and Kuang-tung, and though considerable, is not so large as to affect to any appreciable degree the rough figures of population we hope to establish.[b]

Very little accurate information has come to us as to the death rate in any given locality of China; in fact, the only official data I know of is the death rate in Peking during one year, 1845, for which year we have also the returns of a detailed census of the population within the Peking city walls. These were obtained by Sacharoff and published in his valuable study, cited previously. According to

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[a] Elem. Vital Statistics, p. 15.

[b] The following figures relative to Chinese emigration, taken from Export of April 14, 1904, a German paper devoted to commercial geography, first appeared in Gottwaldt's work on Chinese emigration. The greater part of the Chinese emigration originates in the southern provinces, Shan-tung being the only

them the population of Peking within the walls in 1845 was 1,648,-814, and the number of deaths (exclusive of infants and small children, say, under 5 years of age) during the whole year was 39,438, or about 23.9 per 1,000 inhabitants—by no means an excessive rate.

The death rate among infants, resulting from the highly insanitary conditions in which the whole population, rich and poor, throughout the Empire constantly lives, and also from female infanticide, must be exceedingly high. This latter cause of infant mortality is accountable for a considerably increased death rate in the provinces of Kuang-tung, Fu-kien, Che-kiang, Shan-hsi, Kiang-hsi, An-hui, and in most of the other provinces of the Empire in a lesser degree.[a]

Everything considered—especially the fact that in a very large part of China the people live huddled together in towns and villages, and that nowhere is any attempt ever made toward sanitation or the prevention of the spread of contagious disease—it seems quite safe to put the death rate in China at 30 per 1,000 as a minimum.

northern province that furnishes any large proportion of emigrants from China. The number of Chinese outside of China is as follows:

Country.	Number.	Country.	Number.
Formosa	2,600,000	Macao	74,568
Siam	2,500,000	Burma	40,000
Malay Peninsula	985,000	Australia	30,000
Sunda Islands	600,000	Asiatic Russia	25,000
Hongkong	274,543	Japan	7,000
America	272,829	Korea	3,710
Indo-China	150,000		
Philippines	80,000	Total	7,642,650

The following figures show the number of persons that left China and Hongkong and returned during the last twenty-six years:

China and Hongkong.	Left.	Returned.
Amoy (Fu-kien)	1,629,947	1,309,787
Swatow (Kuang-tung)	1,794,298	1,307,744
Kiung-chou (Hai-nan)	298,772	296,233
Hongkong	1,130,000	1,090,000

[a] See Jour. Nor. Ch. Br. Roy. Asiat. Soc., Vol. XX, p. 25 et seq. Newsholme (Elem. Vital Statistics, 130) says that infant mortality in Europe is lowest in Ireland, with 164.6 in every 1,000, and highest in Russia in Europe, with 422.9 in every 1,000. It must be at least this in China. In Japan, where there exists the same desire as in China to have posterity, the average number of children to a marriage is about 3.5 (Newsholme, op. cit., p. 70). I see no reason to believe that the Chinese are more prolific. In the United States, according to the census of 1900, the annual death rate of the whites, where accurately recorded, was about 17.8 per 1,000.

III.

Let us revert now to the figures given by the Chinese Government for the population at the various periods since 1741 and see whether the annual rates of increase are at all reasonable. This examination is distinctly disappointing; nothing less satisfactory could be conceived. Between 1743 and 1783—during which time China enjoyed extraordinary peace and prosperity, disturbed only by some uprisings of aboriginal tribes in the mountainous regions of the west, and two small rebellions, one in Shan-tung in 1777, the other in Shen-hsi in 1781—no great famines or other natural calamities are recorded. Nevertheless, the annual rate of increase of the population (the enumerations being all presumably made in the same manner, with the same classes excepted), which between 1743 and 1749 was 2.90 per cent, fell from 1749 to 1757 to 0.91 per cent, to rise between 1757 to 1761 to 1.37 per cent, falling again to 0.73 per cent between 1761 and 1767, and to 0.57 per cent from that date to 1771. The next change is phenomenal: Between 1771 and 1776 it was 5 per cent, but immediately after, between 1776 and 1780 it fell, without any known reason, to 0.86 per cent, to rise again between that date and 1783 to 2.34 per cent. The average annual rate of increase during the whole period was 1.83 per cent. In Japan, where much more favorable conditions exist than in China, the average yearly increase of the population from 1872 to 1899 has been only 1.04 per cent.

If we accept the figure given for the population in 1741 (143,412,000) as being closer the truth than subsequent ones, and bearing in mind the reasons given previously for and against a rapid increase of population, we may assume that the population of China proper barely doubled in the hundred years following; consequently in 1842, instead of being, as given in the official enumeration, 413,000,000, it was probably about 250,000,000.

Referring now to the extraordinary causes of mortality from 1842 down to the present day, some of which are mentioned on preceding pages, they may be tabulated as follows:

	Years.	Resulting loss of population.
Famine	1846	225,000
Do	1849	13,750,000
Tai-Ping rebellion	1854–1864	20,000,000
Mohammedan rebellions	1861–1878	1,000,000
Famine	1877–1878	9,500,000
Yellow River inundation	1888	2,000,000
Famine	1892–1894	(?) 1,000,000
Mohammedan rebellion	1894–1895	225,000
Total loss of adults		47,700,000

We are therefore led to the inevitable conclusion that the present population of China proper can not greatly exceed that of 1842, a conclusion reached by another line of argument in 1881 by my friend A. E. Hippisley, in his too-brief study above referred to, and by Mr. Popoff in 1884.

The following considerations tend to strengthen this opinion: The most recent enumeration of the population of China which can lay claim to any value is that of 1885. In it we find that the returns given for six provinces (Chi-Li, Anhoui, Kan-Soo, Kuang-hsi, Yün-nan, and Kuei-Chu) are the same as those given in the earlier census of 1882, but which in this latter were in reality for the year 1879. A comparison of the official estimates for these provinces, with the estimates made by careful foreign investigators is highly interesting.

In the case of the province of Ssŭ-ch'uan, which the board of revenue estimated at 71,073,730 in 1885, all foreign writers agree that it is quite impossible to believe that any such population exists or can exist in it. Its western, northwestern, and southwestern parts are extremely mountainous and very sparsely inhabited. Furthermore, the province contains no extremely populous cities. Ch'êng-tu, the capital, has about 350,000, and Ch'ung-k'ing about 130,000.

The Lyons Commercial Mission, speaking of the year 1895–96, states its belief that the estimates of the maritime customs at Ch'ung-k'ing for 1891 of 30,000,000 to 35,000,000 for the province of Ssŭ-ch'uan is too low, but accepts that of from 40,000,000 to 45,000,000.[a] G. J. L. Litton, writing in 1898, estimated the population of Ssŭ-ch'uan at more than double that given in the enumeration of 1812, and put it at 43,000,000.[b] F. S. A. Bourne, also writing in 1898, says that the population of Ssŭ-ch'uan is probably between 45,000,000 and 55,000,000. In a report in 1904 Hosie gives it as 45,000,000.[c]

Kiang-hsi, for which the official returns give a population of more than 24,000,000, is believed by W. J. Clennell, writing in 1903, to have less than 12,000,000.[d] The same writer estimates the popula- of Fu-kien in 1903 at "certainly under 10,000,000," whereas the Chinese figure for 1885 is 23,502,794. As regards Yünnan, the Lyons Mission[e] puts the population in 1896 at from 7,000,000 to 8,000,000. F. S. A. Bourne, writing of Yün-nan in 1896, says that "according to the best native authority the population is estimated at one-fifth of what it was before the (Mohammedan) rebellion,"[f]

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[a] Mission Lyonnaise d'explor.-commer. en Chine, 1895–1897, part II, p. 232.

[b] Brit. Cons. Reports, No. 457, Misc. series.

[c] Brit. Cons. Reports, No. 458, Misc. series, p. 49. Blue Book; China, No. 5 (1904), p. 4.

[d] Brit. Parl. Blue Book; China, No. 1, 1903.

[e] Op. cit., part II, p. 129.

[f] Rep. Blackburn Chamber Commerce, p. 91.

while Litton, in 1903, thought it was "not over 10,000,000."[a] The Chinese estimate of the population of this province in 1879 (the same figure is given for 1885) was 11,721,576, but only two years before that, in 1877, General Mesney[b] placed it at 5,600,000.

Kuei-chou in or about 1896 was thought to have about 7,000,000 inhabitants,[c] in this agreeing with the Chinese estimate.

Without going any further we see that for the five provinces above mentioned foreign investigators substantially agree that the Chinese estimates are too large by some 56,000,000. All the Chinese figures are one-half to one-third too high. I have not the least doubt that the same reduction must apply to the estimates for most of the other provinces, the error in excess increasing presumably with the density of the population. The conviction is therefore forced on me that the present population of China proper does not exceed 275,000,000, and is probably considerably under this figure.

The population of China is most unevenly distributed. In certain sections, for example, around Swatow, and in portions of Ho-nan, Shan-tung, and Chih-li, it is extraordinarily dense, while in others, as Kan-su, Yün-nan, Kuei-chou, and Kuang-hsi, it is surprisingly sparse. Guesses of the population based on partial returns from some densely populated center would give a most erroneous idea of the population not only of the province as a whole, but of even a smaller division of the country. I have traversed several times all the northern provinces of China—Chih-li, Shan-hsi, Shen-hsi, and Kan-su—and can vouch for the fact that in none of them does the population appear to exceed in numbers what the soil can easily support. The absence of easy lines of communication over which surplus produce can be readily exported, and the fact that the Chinese do not raise cattle or any domestic animals in considerable numbers, tend to restrict the areas cultivated by the farmer. It seems certain that China could support a much larger population than it now has—a condition which could not exist if the population had reached the enormous figure which imaginative writers give us. I am confirmed in this opinion by such a careful observer as F. S. A. Bourne, who, referring to the journey of the Blackburn Chamber of Commerce mission,[d] which traversed the whole Yang-tzŭ Valley and southwestern China, says: "From what we have seen on this journey I should say that China could support twice her present population, and that each man

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[a] Brit. Parl. Blue Book; China, No. 3, 1903.

[b] Journ. Ch. Br. Roy. Asiat. Soc., XXV, p. 483.

[c] Mission Lyons., part II, p. 207.

[d] Rep. of mission to China of Blackburn Chamber of Commerce, 1896–97, p. 111.

might be twice as well off as he is now; and this without any revolutionary change in their present manner of life." [a]

Enumerations of the population of China, 1761, 1812, 1842, 1882, and 1885.

Provinces.	1761.	1812.	1842.	1882.	1885.
Chih-li	15,222,040	27,990,871	36,879,838	* 17,937,000	* 17,937,005
Shan-tung	25,180,734	28,958,764	29,529,877	36,247,835	36,545,704
Shan-hsi	9,768,189	14,004,210	17,056,925	12,211,453	10,791,341
Ho-nan	16,332,570	23,037,171	29,069,771	22,115,827	22,117,036
Kiang-su	23,161,409	37,843,501	39,646,924	20,905,171	21,259,989
An-hui	22,761,030	34,165,059	36,596,988	* 20,596,988	* 20,596,988
Fu-kien	8,063,671	14,779,158	25,799,556	25,000,000	23,502,794
Che-kiang	15,429,692	26,256,784	30,437,974	11,588,692	11,684,348
Hu-pei	8,080,603	27,370,098	28,584,564	33,365,005	33,600,492
Hu-nan	8,829,320	18,652,507	20,048,969	21,002,604	21,005,171
Shen-hsi	7,412,014	10,207,256	10,309,769	* 8,432,193	3,276,967
Kan-su		15,354,875	19,512,716	* 5,411,188	* 5,411,188
Ssŭ-ch'uan	2,782,976	21,435,678	22,256,964	67,712,897	71,073,730
Kuang-tung	6,797,597	19,174,030	21,152,603	29,706,249	29,740,055
Kuang-hsi	3,947,414	7,313,895	8,121,327	* 5,151,327	* 5,151,327
Yün-nan	2,078,802	5,561,320	5,823,670	* 11,721,576	* 11,721,576
Kuei-chou	3,402,722	5,288,219	5,679,128	* 7,669,181	* 7,669,181
Kiang-hsi	11,006,640	23,046,999	26,513,889	24,534,118	24,541,406
Total	190,257,423	360,440,395	413,021,452	381,309,304	377,636,198

The figures given in the censuses of 1761, 1842, 1882, and 1885 were supplied to Father Amiot, Sacharoff, Popoff, and Rockhill by the Chinese board of revenue. Figures in the returns for 1882 and 1885 marked with an asterisk are those given to Sacharoff for the year 1879. They are the latest official estimates.

The figures given under the census of 1812 are taken from Sacharoff, whose authority was presumably the official Ta Ch'ing Hui-tien.

[a] In a most interesting study entitled "Tenure of Land in China and the Condition of the Rural Population" (Journ. Ch. Br. Roy. Asiat. Soc., N. S., XXIII, pp. 59–174) we find it stated (pp. 76–79) on excellent authority that "it is impossible to say with any sort of exactness what proportion of the whole soil of China is tilled by peasant owners, but probably it can not be put at less than one-half. The other moiety is owned in great measure by retired officials and their families, the class known as the literati and gentry. * * * Considerable tracts of land are owned by such families, and it is the invariable rule in these cases to lease the land to small farmers. In the central and populous parts of China these holdings are exceedingly small, often less than an English acre, seldom larger than three or four acres. * * * Most lands yield one or more subsidiary crops in the course of the year, besides the principal crop. * * * On the frontier provinces, where the soil is poorer and the population more sparse, the size of the holdings is in general much larger than in the central provinces, and the people would seem as a rule to be better off. But as population increases there seems everywhere to be a strong tendency for holdings to become reduced to the minimum size that will support a single family. The more fertile the soil the smaller the farms and the more minute the subdivision. How marvelously fertile the soil is under favorable circumstances will be seen from the fact that * * * one mow (6.6 to an acre) will support one individual. On this basis a square mile is capable of supporting a population of 3,840 persons."

CHINESE ARCHITECTURE.[a]

By Stephen W. Bushell, C. M. G., B. Sc., M. D.

The first impression given by the view of a Chinese city from the parapet of the city wall—whether it be Tientsin, with the 150,000 houses of its population of shopmen and artisans, or Peking, with its temples, its imperial and princely palaces, and its public buildings—is that of a certain monotony, resulting from the predominance of a single type of architecture. After a long residence this impression still remains, and it is very rarely that a building stands out which is not reducible to one general formula.

China, in fact, in every epoch of its history and for all its edifices, civil or religious, public or private, has kept to a single architectural model. Even when new types have been introduced from the West under the influence of Buddhism and Mohammedanism, the lines have become gradually toned down and conformed to his own standard by the leveling hands of the Chinese mason. It is a cardinal rule in Chinese geomancy that every important building must face the south, and the uniform orientation resulting from this adds to the general impression of monotony.

The most general model of Chinese buildings is the t'ing. This consists essentially of a massive roof with recurved edges resting upon short columns. The curvilinear tilting of the corners of the roof has been supposed to be a survival from the days of tent dwellers, who used to hang the angles of their canvas pavilions on spears; but this is carrying it back to a very dim antiquity, as we have no records of the Chinese except as a settled agricultural people. The roof is the principal feature of the building and gives to it when finished its qualities of grandeur or simplicity, of strength or grace. To vary its aspect the architect is induced occasionally to double, or even to triple, it. This preponderance of a part usually sacrificed in western architecture is justified by the smaller vertical

[a] Chapter III, Chinese Art, by Stephen W. Bushell; published by the board of education, South Kensington, Victoria and Albert Museum. London, 1904. Reprinted by permission of the controller of His Majesty's stationary office.

elevation of the plan, and the architect devotes every attention to the decoration of the roof by the addition of antefixal ornaments, and by covering it with glazed tiles of brilliant color, so as to concentrate the eye upon it. The dragons and phenixes posed on the crest of the roof, the grotesque animals perched in lines upon the eaves, and the yellow, green, and blue tiles which cover it are never chosen at random, but after strict sumptuary laws, so that they may denote the rank of the owner of a house or indicate the imperial foundation of a temple.

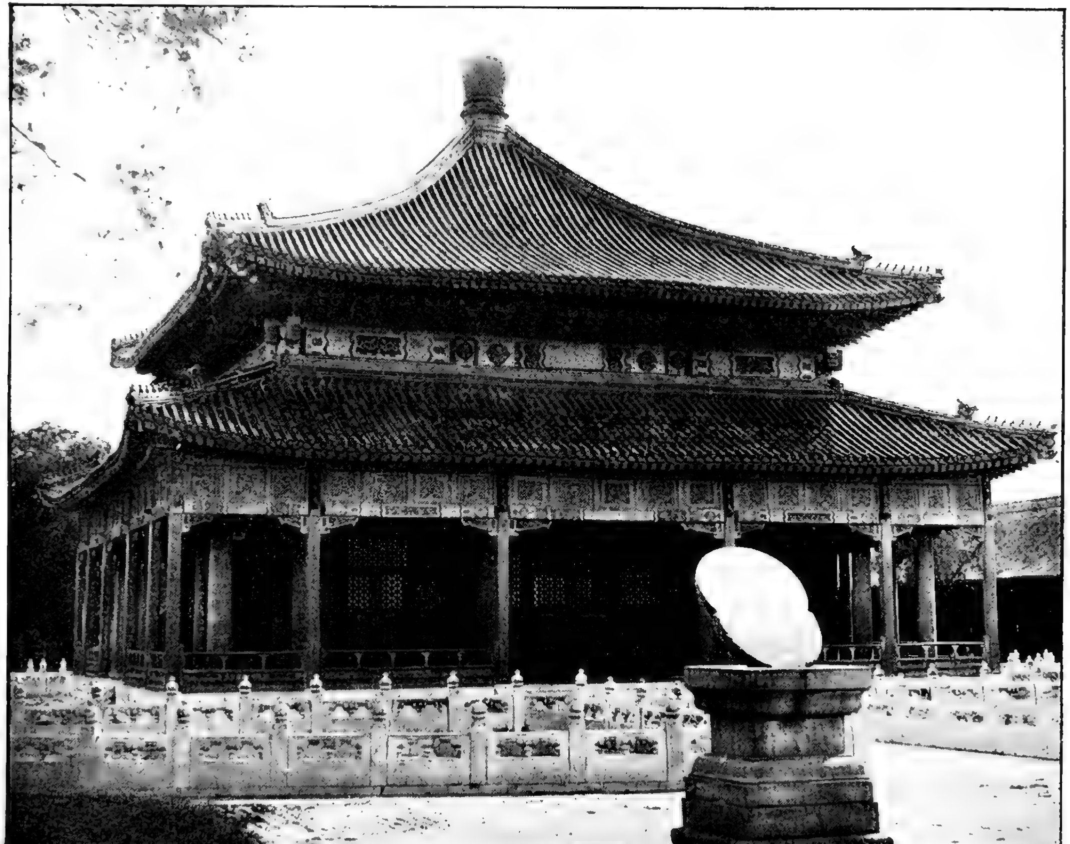
The great weight of the roof necessitates the multiple employment of the column, which is assigned a function of the first importance. The columns are made of wood; the shaft is generally cylindrical, occasionally polyhedral, never channeled; the capital is only a kind of consol, squared at the ends or shaped into dragons' heads; the pedestal is a square block of stone chiseled at the top into a circular base on which the shaft is posed. The pedestal, according to rule, ought not to be higher than the width of the column, and the shaft not more than ten times longer than its diameter. Large trunks of the Persea nanmu from the Province of Ssŭchuan are floated down the Yangtze River to be brought to Peking to be used as columns for the palaces and large temples.

The nanmu is the tallest and straightest of Chinese trees, the grain improves by age, and the wood gradually acquires a dead-leaf brown tint, while it preserves its aromatic qualities, so that the superb columns of the sacrificial temple of the Emperor Yung Lo (pl. I), which date from the early part of the fifteenth century, still exhale a vague perfume. The pillars are brightened with vermilion and gold, but it is the roof which still attracts most attention, in the interior as well as outside, the beams being often gorgeously inlaid with colors and the intervening ceiling geometrically divided into sunken panels worked in relief and lacquered with dragons or some other appropriate designs.

The stability of the structure depends upon the wooden framework; the walls, which are filled in afterwards with blocks of stone or brickwork, are not intended to figure as supports; the space, in fact, is often occupied entirely by doors and windows, carved with elegant tracery, of the most flimsy character. A Chinese fabric so far is curiously analogous to a modern American building of the newest type, with its skeleton framework of steel filled in with dummy walls.

The Chinese seem to have a feeling of the innate poverty of their architectural designs and strive to break the plain lines with a profusion of decorative details. The ridge poles and corners of the sagging roofs are covered with finial dragons and long rows of fantastic animals, arranged after a symbolism known only to the initiated, the eaves are underlaid with elaborately carved woodwork

SACRIFICIAL HALL OF YUNG LO, MING TOMBS NEAR PEKING. FIFTEENTH CENTURY.



PI YUNG KUNG. IMPERIAL HALL OF THE CLASSICS, NATIONAL UNIVERSITY, PEKING EIGHTEENTH CENTURY.

brilliantly lacquered, the walls are outlined with bands of terra-cotta reliefs molded with figures and floral sprays; but in spite of everything the monotony of the original type is always apparent.

Chinese buildings are usually one-storied and are developed horizontally as they are increased in size or number. The principle which determines the plan of projection is that of symmetry. The main buildings and wings, the side buildings, the avenues, the courtyards, the pavilions, the motives of decoration, all the details, in fact, are planned symmetrically. The architect only departs from this formal rule in the case of summer residences and gardens, which are, on the contrary, designed and carried out in the most capricious fashion. Here we have pagodas and kiosques elevated at random, detached edifices of the most studied irregularity, rustic cottages and one-winged pavilions, dotted down in the midst of surroundings of the most complicated and artificial nature, composed of rockeries, lakes, waterfalls, and running streams spanned by fantastic bridges, with an unexpected surprise at every turn.

Ruins in China are rare, and we must turn to books to get some idea of ancient architecture. The first large buildings described in the oldest canonical books are the lofty towers called "t'ai," which were usualy square and built of stone, rising to the height sometimes of 300 feet, so that they are stigmatized as ruinous follies of the ancient kings. There were three kinds of t'ai, one intended as a storehouse for treasures, a second built within a walled hunting park for watching military exercises and the pleasures of the chase, and a third, the kuan hsiang t'ai, fitted up as an astronomical observatory. The Hsia dynasty, of the second millenium B. C., was renowned for its buildings and irrigation works; their predecessor, Shun, as a patron of the potter's art; while among their successors the Shang dynasty was celebrated for its sacrificial vessels and wine cups, the Chou dynasty for the finish of its hunting and war chariots. Among the later representatives of the t'ai are the towers of the great wall, which are built of stone with arched doors and windows—the Chinese would seem always to have employed the arch in stone architecture—the storied buildings dominating the gateways and angles of the city walls, often used to store arms, and the observatory of Peking, which is also a square tower mounted upon the city wall. When the tower is planned of oblong section, broader than it is deep, it is technically called a "lou."

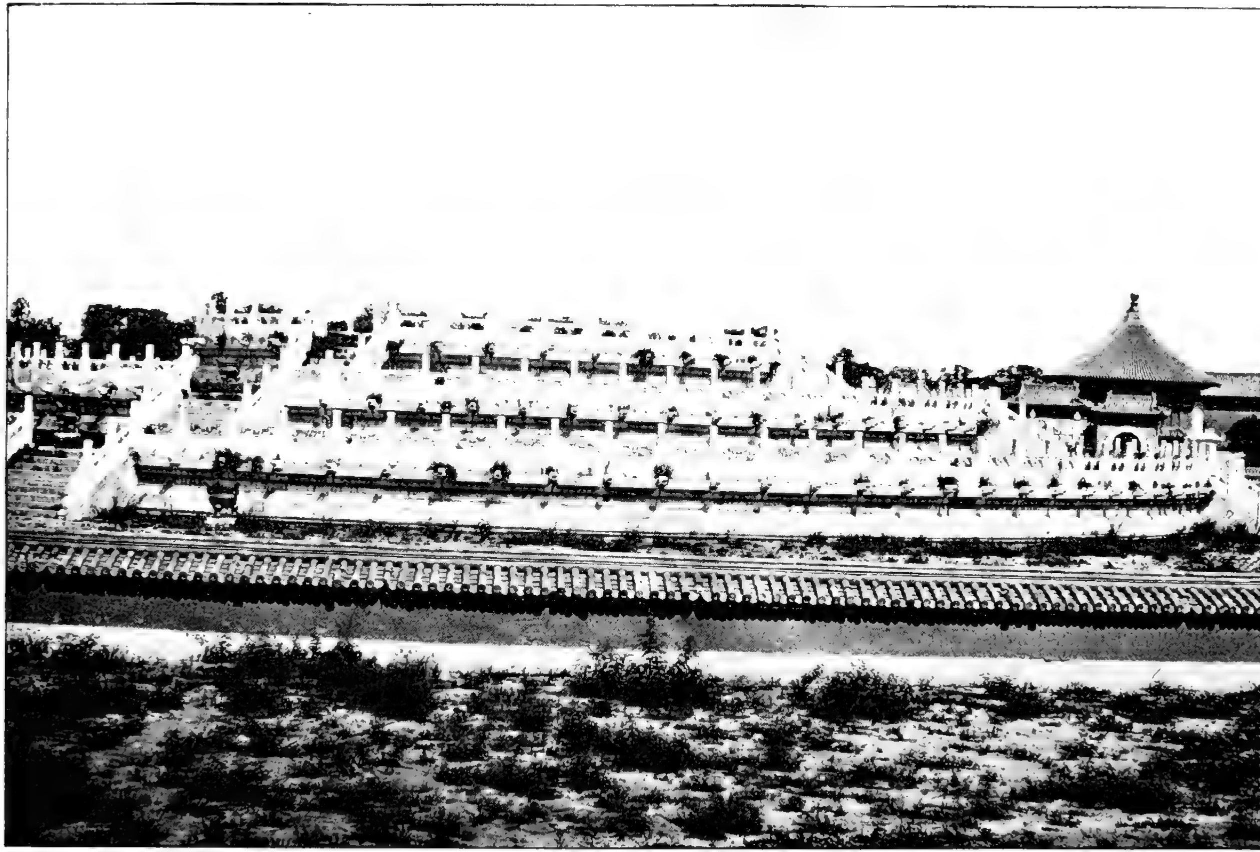
Chinese buildings might be classified as civil, religious, and funereal, but it is more convenient to group all together in the few illustrations allowed in our limited space. The Hall of the Classics, called "Pi Yung Kung" (pl. II), was built after an ancient model by the Emperor Ch'ien Lung in Peking, adjoining the national university called "Kuo Tzŭ Chien," where the Temple of Confucius

and the stone drums, as described above, are installed. The Emperor goes there in state on certain occasions to expound the classics, seated upon the large throne within the hall, which is backed by a screen fashioned in the form of the five sacred mountains. It is a lofty square building with a four-sided roof covered with tiles enameled imperial yellow, and surmounted by a large gilded ball, encircled by a pillared veranda under a second projecting roof of yellow tiles. The four sides consist each one of seven pairs of folding doors with tracery panels. It is surrounded by a circular moat with marble balustrades, crossed by four bridges leading to the central doors. On the sides of the courtyard in which it stands are two long cloistered buildings, sheltering about 200 upright stone stelæ covered with inscriptions over the front or back. The inscriptions comprise the complete text of the "nine classics," and were engraved by the Emperor Ch'ien Lung, in emulation of the Han and T'ang dynasties, both of which had the canonical books cut in stone at Si An Fu, the capital of China in their times. The text is divided on the face of the stone into pages of convenient size, so that rubbings may be taken on paper and bound up in the form of books. It was the custom as early as the Han dynasty to take such impressions, a practice which may possibly have first suggested the idea of block printing.

A sundial of antique form is seen mounted on a stone pedestal in the foreground of the picture. On the other side of the hall, the south, stands a magnificent "porcelain" pailou, resembling the one illustrated in plate III, which spans the avenue leading to Wo Fo Ssŭ, the "temple of the sleeping Buddha," in the western hills near Peking. The pedestals and three arches are built of sculptured marble, separated by walls of vermilion stucco from the paneled facing of faience covering the rest of the structure, which is enameled in three colors—yellow, green, and blue—and forms an elaborate framework for the inscribed tablet of white marble enshrined in the center. This tablet, the motive of the erection, displays a short dedicatory formula, composed and presented by the Emperor, which is chiseled and filled in with red in the actual lines of his original brushwork. These archways, which are a characteristic feature of Chinese architecture, are only erected by special authority. They are generally made of wood with tiled roof, and are usually intended as memorials of distinguished men and women. Some, however, are built entirely of stone, like the immense gateway with five portals at the avenue of the Ming tombs. The stone toran of Indian stupas is doubtless the original form from which the Chinese pailou, as well as the Japanese tori, is derived.

One of the grandest and most interesting sights of Peking is the Temple of Heaven, which is within the southern or Chinese city, surrounded by stately cypress trees in the midst of a walled park over

MEMORIAL ARCH OF MARBLE AND GLAZED TERRA COTTA, PAILOU, BUDDHIST TEMPLE OF THE SLEEPING BUDDHA, NEAR PEKING.



THE GREAT ALTAR OF HEAVEN, T'IEN T'AN, SOUTHERN CITY, PEKING.

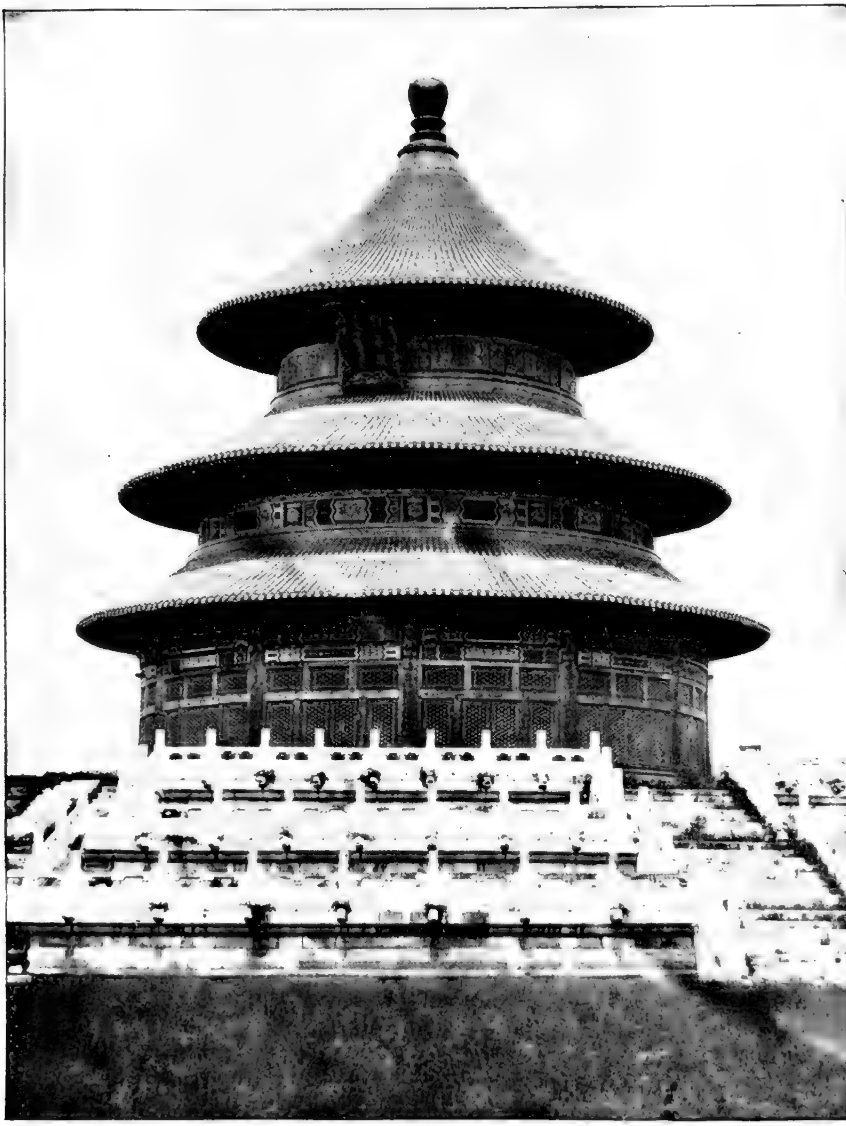
3 miles round. The oxen used in sacrifice are kept in the park, and there are separate inclosures provided for the other sacrificial animals, which include sheep, deer, pigs, and hares. The consecrated meats are prepared in accordance with an ancient ritual in kitchens built for the purpose, to which are attached special slaughterhouses, well houses, and stores for vegetables, fruit, corn, and wine. The Chinese have no idea of vicarious sacrifice, the offerings to their supreme deity are like the precious objects, raiment, and foods which are set forth in ancestral worship. Heaven is not worshiped alone; the ancestral tablets of four of the imperial forefathers are always associated with the tablet of Shang Ti, the "supreme deity," followed by those of the sun, moon, planets, and starry constellations, while the spirits of the atmosphere, winds, clouds, rain, and thunder are ranged in subordinate rank below. Heaven is distinguished by the offering of blue jade pi, a foot in diameter, round and with a square hole in the middle, like the ancient mace-head symbols of sovereignty, and by the bullock being sacrificed as a whole burnt offering. The jade and silk are also burned; twelve rolls of plain white silk and hempen cloth being sacrificed for heaven, one for each of the other spirits; while the banquet piled on the altar in dishes of blue porcelain is proportionately lavish.

The great altar of heaven, T'ien T'an, the most sacred of all Chinese religious structures, is seen in plate IV. It consists of three circular terraces with marble balustrades and triple staircases at the four cardinal points to ascend to the upper terrace, which is 90 feet wide, the base being 210 feet across. The platform is laid with marble stones in nine concentric circles and everything is arranged in multiples of the number 9. The Emperor, prostrate before heaven on the altar, surrounded first by the circles of the terraces and their railings, and then by the horizon, seems to be in the center of the universe, as he acknowledges himself inferior to heaven and to heaven alone. Round him on the pavement are figured the nine circles of as many heavens, widening in successive multiples till the square of 9, the favorite number of numerical philosophy, is reached in the outer circle of 81 stones. The great annual sacrifice on the altar is at dawn on the winter solstice, the Emperor having proceeded in state in a carriage drawn by an elephant the day before, and spent the night in the hall of fasting called Chai Kung, after first inspecting the offerings. The sacred tablets are kept in the building with a round roof of blue enameled tiles behind the altar which is seen on the right of the picture. The furnace for the whole burnt offering stands on the southeast of the altar, at the distance of an arrow flight; it is faced with green tiles, and is 9 feet high, ascended by three flights of green steps, the bullock being placed inside upon an iron grating, under which the fire is kindled. The

rolls of silk are burned in eight openwork iron urns, stretching from the furnace round to the eastward; an urn is added when an Emperor dies. The prayers written upon silk are also burned in these urns after they have been formally presented in worship before the tablets.

To the north of the great altar, which is open to the sky, there is a second three-tiered marble altar conceived in similar lines, but somewhat smaller, called the "Ch'i Ku T'an," or "altar of prayer for grain." This is dominated by the imposing triple-roofed temple presented in plate v, which is covered with tiles of deep cobalt blue shining in the sunlight so as to make it the most conspicuous object in the city. The name of this edifice, as set forth on the framed plaque fixed under the eaves of the upper roof, in Manchu and Chinese script, is Ch'i Nien Tien (temple of prayer for the year). The Emperor goes there early each year in spring to make offerings for a propitious year. It is 99 feet high, the upper roof supported by four stately pillars, the lower roofs by two circles of 12 pillars, all straight trunks of nam-mu trees recently brought up from the southwest, when the temple had to be rebuilt after its destruction by fire. Originally founded by the Emperor Ch'ien Lung, it was rebuilt during the present reign in every detail after the old plan. During the ceremonies inside everything is blue; the sacrificial utensils are of blue porcelain, the worshippers are robed in blue brocades, even the atmosphere is blue, venetians made of thin rods of blue glass, strung together by cords, being hung down over the tracery of the doors and windows. Color symbolism is an important feature of Chinese rites; at the temple of earth all is yellow; at the temple of the sun, red; at the temple of the moon, white, or rather the pale grayish blue which is known as "yueh pai," or moonlight white, pure white being reserved for mourning. The altar of the earth, Ti T'an, is on the north of the city, outside the city wall, and is square in form; the offerings are buried in the ground instead of being burned. The temples of the sun and moon are on the east and west and are also outside the city wall of Peking; the princes of the blood are usually deputed by the Emperor to officiate at these.

A good illustration of the t'ing, which is so characteristic of Chinese architecture, has been given in plate i, from a photograph of the large sacrificial hall of the Emperor Yung Lo. The tombs of the Ming dynasty, called colloquially "Shih-san Ling," "Tombs of the Thirteen (Emperors)," are, as the name indicates, the last resting places of thirteen of the Ming Emperors. The first was buried at Nanking, his capital; the last near a Buddhist temple on a hill west of Peking, by command of the Manchu rulers when they obtained the Empire. The Emperor Yung Lo (1403–1424), who made Peking his capital, choose this beautiful valley for the mausoleum of his house. It is



TEMPLE OF HEAVEN, CH'I NIEN TIEN, SOUTHERN CITY, PEKING.

SHRINE AND ALTAR OF CONFUCIUS, CONFUCIAN TEMPLE, PEKING.

6 miles long, 30 miles distant from Peking to the north, and the imperial tombs are in separate walled inclosures, dotting the slopes of the wooded hills which skirt the valley.

The avenue, with its row of colossal stone figures, has been noticed in the last chapter. At the end of the avenue one comes to a triple gateway leading to a court with a smaller hall, and passes through to reach the main courtyard with the large sacrificing hall, where, by order of the Manchu Emperors, offerings are still presented to the long-deceased ruler of a fallen dynasty by one of his lineal descendants selected for the purpose. The hall is mounted upon a terrace, with three balustrades of carved marble extending all around, ascended by three flights of 18 steps in front and behind, leading to three portals with folding doors of tracery. It is 70 yards long by 30 deep, with a massive tiled roof supported by eight rows of four pillars each. The columns, of Persea nanmu wood, are 12 feet around at the base and over 60 feet high to the true roof, under which there is a lower ceiling, about 35 feet from the floor, made of wood in sunken square panels painted in bright colors. The ancestral tablet is kept in a yellow roofed shrine mounted upon a dais, with a large carved screen in the background, and in front stands a sacrificial table with an incense urn, a pair of pricket candlesticks, and a pair of flower vases ranged in line upon it. Leaving this magnificent hall and passing through another court, planted like those preceding, with pines, arbor-vitæ trees, and oaks, one comes to the actual tomb. A subterranean passage 40 yards long leads to the tumulus, the door of which is closed by masonry, but flights of steps east and west lead to the top of the grave terrace. Here, in front of the mound and immediately above the coffin passage, is the tombstone, an immense upright slab, mounted upon a tortoise, inscribed with the posthumous title, "Tomb of the Emperor Ch'êng Tsu Wên." The tumulus is more than half a mile in circuit, and, though artificial, looks like a natural hill, being planted with trees to the top, among which the large-leafed oak (*Quercus bungeana*), on which wild silkworms are fed, is conspicuous.

The usual paraphernalia of the shrine of an ancestral temple are seen in plate VI, which is a view of the interior of the Confucian temple in the Kuo Tzŭ Chien, the old national university of Peking. The ancestral tablet is seen dimly in the center of the picture enshrined in an alcove between two pillars. The tablet, 2 feet 5 inches high and 6 inches broad, mounted upon a pedestal 2 feet high, is inscribed in gold letters upon a lacquered vermilion ground in Manchu and Chinese, "The tablet of the spirit of the most holy ancestral teacher, Confucius." The pillars are hung with laudatory couplets, and the beams with dedicatory inscriptions, one of which is penciled by each succeeding Emperor in token of his veneration for the sage. The

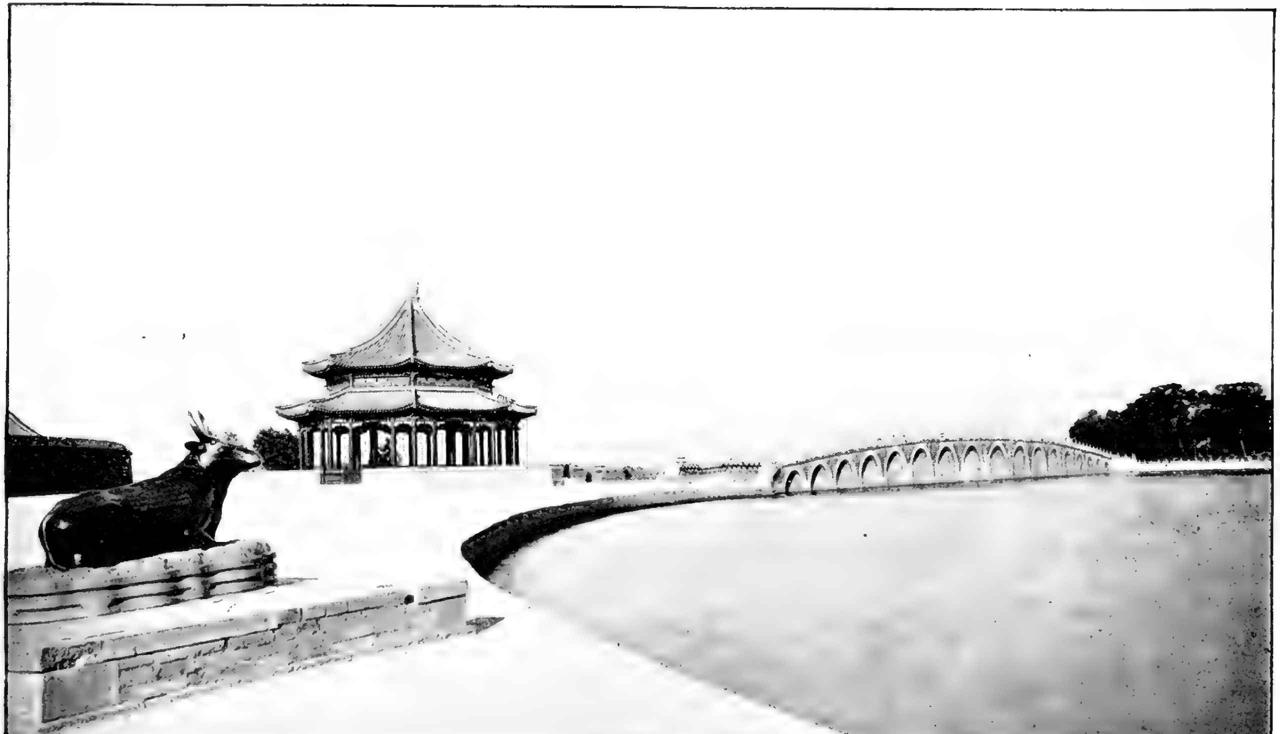
line of four large characters above, for example, Wan shih shih piao, "the model teacher of myriad ages," was composed and written by the Emperor K'ang Hsi in the twenty-fourth year of his reign (A. D. 1685), and is authenticated by his seal attached to the inscription. The wu kung ("sacrificial set of five"), comprising incense urn, pricket candlesticks, and flower vases made of bronze, is here posed on separate stands of white marble. In front of all is the table ready for the sacrificial offerings, which are regularly presented at spring and autumn. The rest of the large hall is lined with tablets of Tsêng Tzŭ, Mencius, and the other distinguished sages and disciples of Confucius, whose spirits are officially worshiped in turn on the same ceremonial occasions.

The ornamental lines of an open garden pavilion, which also comes under the general heading of t'ing, are fairly exhibited in plate VII, in spite of the half-ruined condition of the picturesque structure, as it appeared when it was photographed after the destruction of the summer palace during the Anglo-French expedition of 1860. It stands on the border of the lake at Wan Shou Shan, having recently been repaired for the Empress Dowager, who has tea served there for her European guests, brought from Peking in state barges towed by steam tugs. It is hung with bronze bells which tinkle softly in the breeze. The central building, as well as the two pailous spanning the avenues through which it is approached, has its woodwork gaily decorated with painted scrolls, relieved by graceful bands of open fret, and it is roofed over all with yellow enameled tiles. Notice the stone monsters at the four corners mounted upon short octagonal pillars with decorated capitals, which might be remote descendants of the ancient Hindu lion pillars of Asoka's time molded on modern Chinese lines.

A view of the K'un-ming Hu, the lake which has just been referred to, is given in plate VIII. The name comes down from the Han dynasty, when it was given to a lake near Si-an Fu, the metropolis of the period in the Province of Shensi, on which the Emperor Wu Ti had a fleet of war junks maneuvering to exercise the sailors for the conquest of Cochin China. The present lake, which is 4 miles in circuit, has been the first of the inland waters of China to have modern armed steamers in its waters, when the Empress Dowager had a review of model ships built at her command the year before the Boxer troubles. The imperial pavilion, erected by the Emperor Ch'ien Lung on the spot where the best view of the lake was to be obtained, is a prominent object in the picture. He was fond of inditing verses, and a favorite ode of his composition on the beauty of the surrounding scene is incised there on a marble stele.

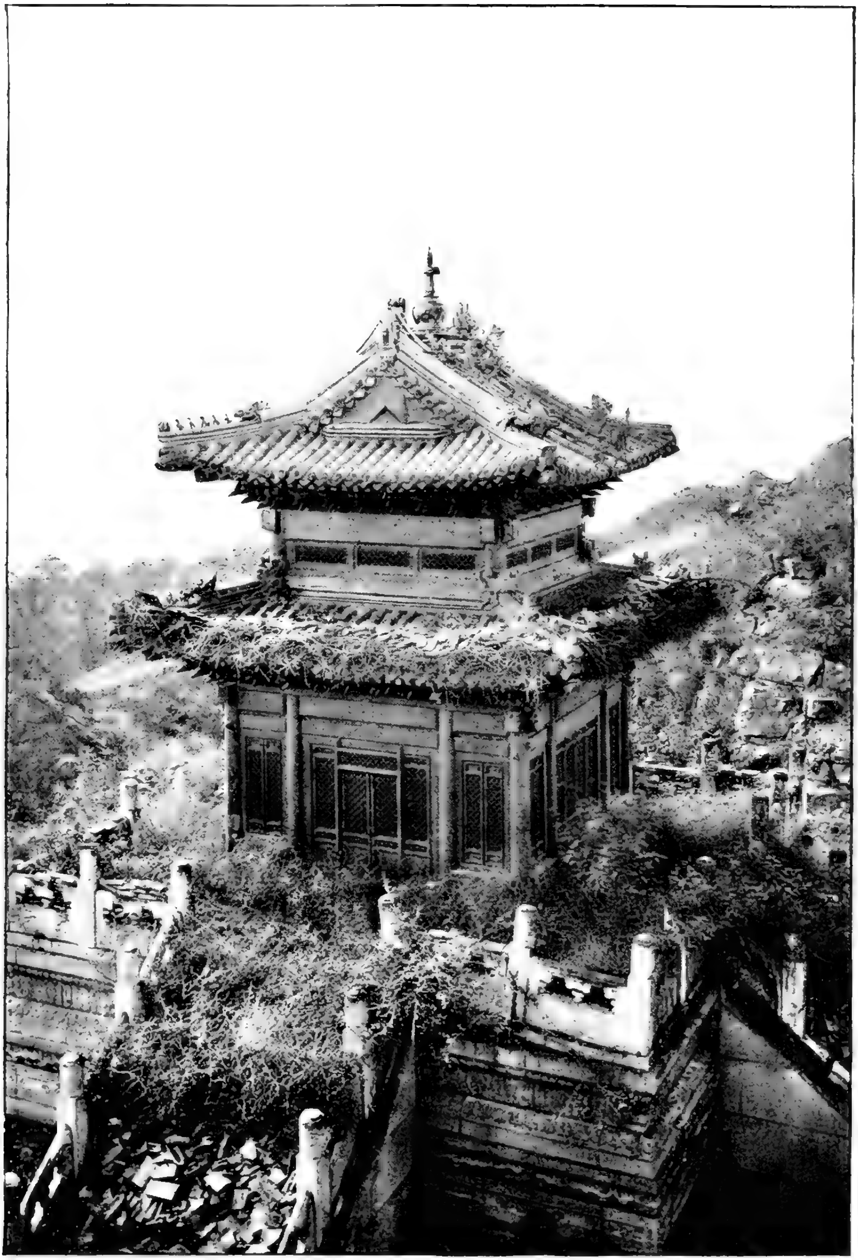
The bronze ox in the foreground was also molded under his auspices, and it is inscribed, as may be seen in the picture, with dedicatory stanzas written by the imperial brush, which are printed

GARDEN PAVILION AT WAN SHOU SHAN, IMPERIAL SUMMER PALACE, NEAR PEKING



K'UNMING HU. LAKE AT WAN SHOU SHAN, IMPERIAL SUMMER PALACE, NEAR PEKING.

HUNCHBACK BRIDGE, LO-KO CH'IAO, IMPERIAL SUMMER PALACE, NEAR PEKING.



BRONZE BUDDHIST SHRINE AT WAN SHOU SHAN, IMPERIAL SUMMER PALACE, NEAR PEKING.

in the official description of Peking. The ox, as the chief agricultural animal, has been sacred in China from the earliest times, and it still has a foremost place in rustic spring ceremonial, being molded in clay for the purpose. The verses, which are too long to be quoted in full, relate how the Emperor has taken as his model the ancient Yu of Hsia, whose eulogy was handed down on an iron ox after he had carried off the river floods; how he has propitiated the sacred ox, a constellation of the zodiac, the queller of dragons and river monsters, and installed its figure here to preside forever over the irrigation channels which he has dug for the benefit of the villagers, concluding with the peroration:

> Men praise the warrior emperor of the Han,
> We prefer as our example the ancient Yao of T'ang.

The marble bridge of 17 arches in the picture is a remarkable example of the fine stone bridges for which the neighborhood of Peking has been celebrated since Marco Polo described the many-arched bridge of Pulisanghin, with its marble parapets crowned with lions, which spans the river Hunho and is still visible from the hills which form the background of the summer palace. Our bridge, which was built in the twentieth year of Ch'ien Lung (A. D. 1755), leads from the cemented causeway to an island in the lake with an ancient temple dedicated to the dragon god and called Lung Shên Ssŭ, the name of which was changed by Ch'ien Lung to Kuang Jun Ssŭ, the "Temple of Broad Fertility," because the Emperor, as a devout Buddhist, objected to the deification of the Naga Raja, the traditional enemy of the faith.

A characteristic bridge of different form on the western border of the lake is illustrated in plate IX. This is called, from its peculiar shape, the Lo-ko Ch'iao or Hunchback Bridge, and has only one arch, 30 feet high, with a span of 24 feet. Its height allows the imperial barges to pass underneath without lowering their masts, and it is withal one of the most picturesque features of the landscape.

A bronze temple which stands on the southern slope of the hill of Wan Shou Shan is seen in plate X. It is 20 feet high, double roofed, and designed in the usual lines, but every detail is executed in bronze, the pillars, beams, tiles, tracery of doors and windows, and all ornamental appendages having been previously molded in metal. This is one of the few buildings which defied the fire in 1860. It stands on a marble foundation with carved railings and steps, which are piled with bricks and bushes to keep off pilferers of the valuable material. The miniature stupa, or dagaba, which crowns the crest of the roof, is an attribute of a Buddhist building, and this one, in fact, is intended to be a shrine for the historical Buddha, as it contains a gilded image of Sakyamuni enthroned on a lotus thalamus, with the usual set of utensils for burning incense.

The pagoda illustrated in plate XI from the grounds of the imperial summer palace of Yuan-ming Yuan is a fine example of architectural work in glazed faience, in the style of the famous porcelain tower of Nanking. The Nanking pagoda was razed to the ground by the Taiping rebels in the year 1854, but specimens of the tiles and ornamental fixtures are preserved in the museum. The practice of facing buildings, inside as well as outside, with slabs or tiles of faience coated with colored glazes is very ancient in Asia. The processions of archers and lions lining the walls of the staircases of the palaces of Darius at Susa are striking examples of early date, and the art was further developed in the decoration of the mosques and tombs of Persia and Transoxiana during the middle ages. It dates in China from the later Han dynasty, during which green glazed pottery first came into vogue, and was revived in the earlier half of the fifth century, when artisans are recorded to have come from the Yueh-ti, an Indo-Scythian kingdom on the northwestern frontiers of India, and to have taught the Chinese the art of making different kinds of liu-li, or colored glazes. The center of the manufacture to-day is Po-shan Hsien, in the province of Shantung, where slabs and rods of colored frits are produced, to be exported to all parts of the country, whenever required for the decoration of cloisonné and painted enamels on metal, porcelain, or faience. The imperial potteries for this kind of work are established in a valley of the western hills near Peking, as well as in the mountains in the vicinity of Mukden, the capital of Manchuria. Figures of Buddha and other temple divinities are fabricated at these works, as well as the many kinds of antefixal ornaments, facings, and colored tiles required for imperial buildings. When a suite of European palaces was designed by the Jesuits Attiret and Castiglione for Yuan-ming Yuan, enameled fountains, elaborate screens with trophies, helmets and shields, balustrades with ornamental flowerpots and the like were executed at these potteries in orthodox Italian style.

The glazes used in the decoration of this pagoda are five in number: A deep purplish blue derived from a compound of cobalt and manganese silicates; a rich green from copper silicate; a yellow, approaching the tint of the yolk of an egg, from antimony; a sang de bœuf red from copper mixed with a deoxidizing flux, and a charming turquoise blue derived from copper combined with niter. The last two are more sparingly employed than the rest. The fivefold combination is intended to suggest the five jewels of the Buddhist paradise. A jeweled pagoda, pao t'a, of portentous dimensions, is supposed, in the Buddhist cosmos, to tower upward from the central peak of the sacred mount Meru, to pierce the loftiest heaven, and to illuminate the boundless ether with effulgent rays proceeding from the three

PORCELAIN PAGODA, YUAN MING YUAN, IMPERIAL SUMMER PALACE, NEAR PEKING.

PAGODA, LING KUANG SSU, WESTERN HILLS, NEAR PEKING.
SEVENTH CENTURY.

jewels of the law and the revolving wheel with which it is crowned. Speculative symbolism of this kind is carried out in the form of the pagoda. The base, four-sided, represents the abode of the four maharajas, the great guardian kings of the four quarters, whose figures are seen enthroned here within the open arches. The center, octagonal, represents the Tushita heaven, with eight celestial gods, Indra, Agni, and the rest, standing outside as protectors of the eight points of the compass; this is the paradise of the Bodhisats prior to their final descent to the human world as Buddhas, and Maitreya, the coming Buddha, dwells here. The upper story, circular in form, represents the highest heaven, in which the Buddhas reside after attaining complete enlightenment; the figures in niches are the five celestial Buddhas, or Jinas, seated on lotus pedestals.

The ordinary pagoda of 13 stories, octagonal in section, solidly built of brick upon massive stone foundations, is seen in plate XII. This one, which dates from the end of the seventh century, is attached to the temple of Ling-kuang Ssŭ, in the western hills near Peking, and it is plainly visible from the top of the city wall 12 miles distant. It is not certain, however, whether it be still standing, as it was unfortunately condemned to be blown up by dynamite in 1900, because the Boxers had made this temple their headquarters. The Buddhist monks have always chosen the most picturesque spots for their monasteries, and there are no less than eight temples on the slope of this particular hill, which is about 800 feet high, and many more in the vicinity. Some have imperial traveling palaces, called Hsing Kung, in adjoining courts; all have guest rooms, k'o t'ang, as part of the original plan for the entertainment of strangers and passing pilgrims.

The general plan of a Buddhist temple resembles that of a secular residence, consisting of a series of rectangular courts, proceeding from south to north, with the principal edifice in the center and the lesser buildings at the sides. A pair of carved stone lions guard the entrance, flanked by lofty twin columns of wood which are mounted with banners and lanterns on high days and holidays. The gateway is large and roofed to form a vestibule, in which are ranged, on either side, gigantic figures of the four great kings of the devas, Ssŭ ta t'ien wang, guarding the four quarters; while in the middle are generally enshrined small effigies of Maitreya, the Buddhist Messiah, conceived as an obese Chinaman with protruberant belly and smiling features, and of Kuan Ti, the state god of war, a deified warrior, represented as a mailed figure in the costume of the Han period, seated in a chair.

Passing through the vestibule, one sees on either side of the first court a pair of square pavilions containing a bronze bell and a huge wooden drum, and in front the main hall of the temple, called Ta

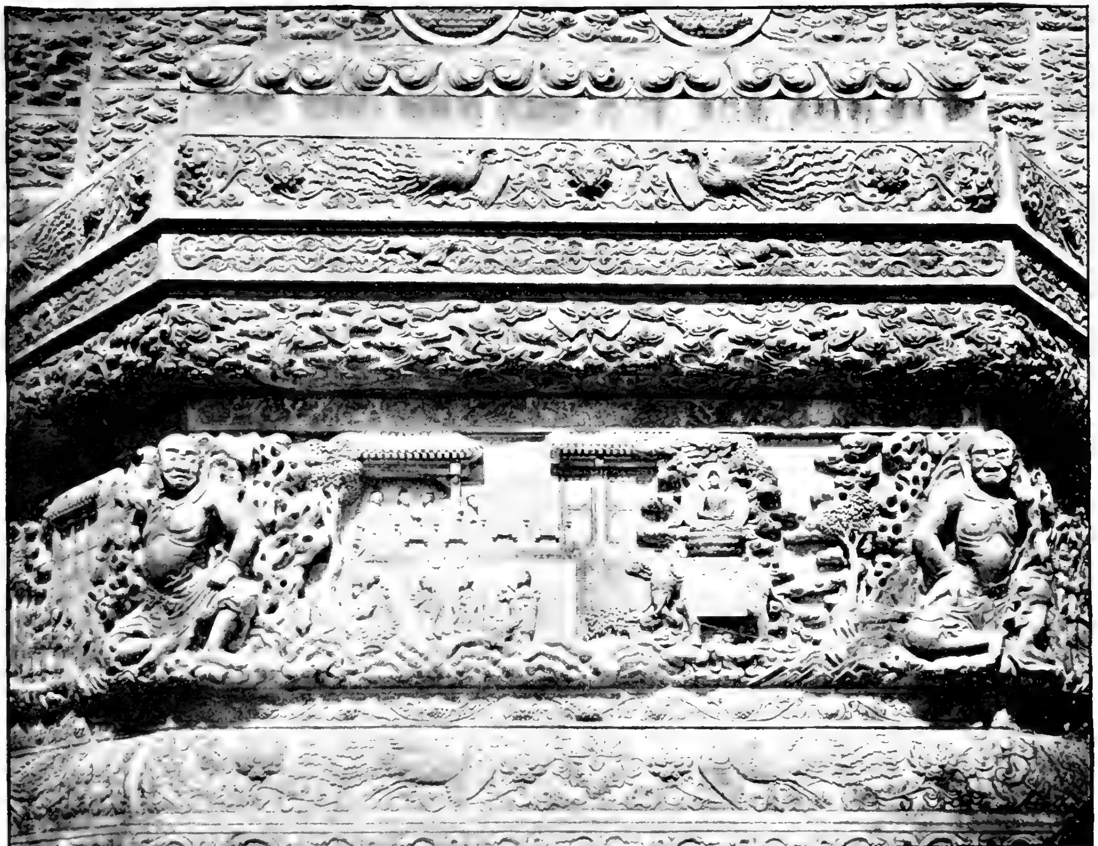
hsiung pao tien, the "jeweled palace of the great hero"—that is to say, Sakyamuni, the historical Buddha. He is always the central figure of the imposing triad enthroned upon lotus pedestals inside; the two others are usually Ananda and Kasyapa, his two favorite disciples. Along the side walls are ranged life-size figures of the eighteen Arhans (Lohan), with their varied attributes, disciples who have attained the stage of emancipation from rebirth. Behind the principal court there is often another secluded courtyard sacred to Kuan Yin, the "goddess of mercy," where Chinese ladies throng to offer petitions and make votive offerings. Avalokitesvara (Kuan Yin) is installed here in the central hall, often supported by two other Bodhisattvas, Manjusri (Wên-shu), the "god of wisdom," and Samantabhadra (Pu-hsien), the "all-good." The surrounding walls are usually studded with innumerable small figures of celestial bodhisats, tier upon tier, molded in gilded bronze or clay, and posed in niches. The wing buildings in this court are devoted to the deceased inmates of the monastery, and contain portraits and relics of bygone abbots and monks. The side cloisters are two-storied in the large temples, the treasures of the monastery being stored above, as well as libraries, blocks for printing books, and the like.

An outer wall encircles the whole, inclosing besides a stretch of the hill slope, which affords ample space for the separate accommodation of the higher dignitaries of the establishment, for kitchens and stables, storehouses of fruit and grain, open pavilions for sipping tea and enjoying the view, and secluded quarters in terraced villas for the residence of occasional visitors.

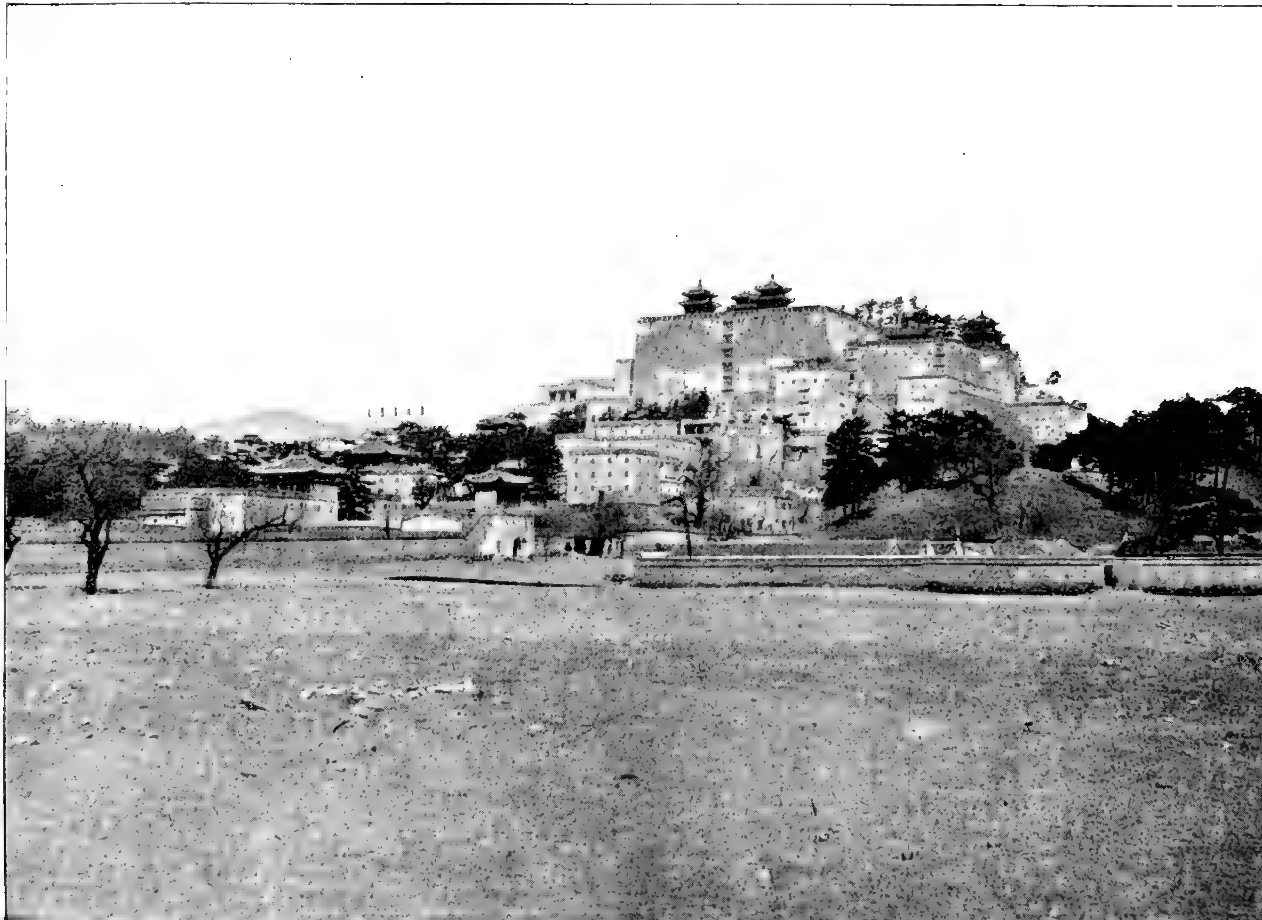
The Buddhist triad displayed in plate XIII was taken from the interior of the large hall of the temple called Huang Ssŭ, which was built by the founder of the reigning Manchu dynasty for the residence of the fifth Grand Lama of Tibet, when the high dignitary came on a visit to Peking in the year 1647, and to which the stupa shown in plates XIV–XV is attached. This is a lama temple, and the large images of gilded bronze represent Avalokita, Manjusri, and Vajrapani, seated upon lotus pedestals, the smaller standing figures being two attendant bodhisats carrying the alms bowl and chowry brush. The five little images posed in line in front of the pedestal of Avalokita represent the celestial Buddhas, Amitabha and the rest, and an image of Sakyamuni, the earthly reflex of Amitabha, is mounted in front. The massive altar tables and the sacrificial utensils and ritual symbols placed upon them are all chiseled in marble. The canopied background of the large figures is carved in wood and gilded, with the aureole encircled by a frieze of elephants, lions, and mythical animals, culminating in coiling dragons, overawed by cherub-like garudas, which brood over the three jewels of the faith, the whole being enveloped in a broad, rolling band of scrolled flames.

BUDDHIST TRIAD, INTERIOR OF LAMA TEMPLE, HUANG SSU, NEAR PEKING.

STUPA OF SCULPTURED MARBLE, PAI T'A SSŬ, PEKING. EIGHTEENTH CENTURY.



INCARNATION OF A BODHISATTVA, SCULPTURED IN MARBLE, PAI T'A SSŬ, PEKING. EIGHTEENTH CENTURY.



LAMA TEMPLE AT JEHOL, BUILT BY K'ANG HSI (1622-1722). MODELED AFTER POTALA TEMPLE AT LASSA.

The difference between Lamaism and the ordinary form of Chinese Buddhism is shown most strongly by their discordant conceptions of Maitreya, the coming Buddha. His Chinese statuette has been described above, under the name of Milo Fo, as it is placed in the vestibule of a temple, and he is, besides, worshiped at many private houses and shops, so that he is almost as popular a divinity with men at Kuan Yin, the so-called "goddess of mercy," is with Chinese women. In Japan Hotei, the merry monk with a hempen bag, is claimed by some to be an incarnation of the Bodhisat Maitreya, and is endowed there with national traits in the spirit of playful reverence which characterizes the Japanese artist. The Lama conception of Maitreya, on the contrary, is that of a dignified and colossal figure, robed as a prince, with the jeweled coronet of a bodhisat, towering above the other crests of the roofs of a lamasery, or occasionally carved on the face of a cliff. There is a gigantic image of Maitreya in the Yung Ho Kung, at Peking, made of wood, over 70 feet high, the body of which passes through several successive stories of the lofty building in which it is installed. The devout votary must climb a number of winding staircases to circumambulate the sacred effigy in the orthodox way, till he finally reaches the immense head. Yung Ho Kung was the residence of the Emperor Yung Chêng before he came to the throne, and it was dedicated to the Lama Church, in accordance with the usual custom, when he succeeded in 1722. When the Emperor visits the temple a lamp is lit over the head of Maitreya, and a huge praying wheel on the left, which reaches upward as high as the image, is set in motion on the occasion. The resident lamas, mostly Mongols, number some 1,500, under the rule of a Gegen, or living Buddha, of Tibetan birth, who rejoices in the title of Changcha-Hutuktu Lalitavajra. An excellent portrait of this dignitary, from a miniature on silk, is given in Prof. A. Grunwedel's Buddhist Art in India.

Lamaism may be said to rank as the state church of the reigning Manchu dynasty. The Lama temple illustrated in plate XVI was built by the Emperor K'ang Hsi, in the vicinity of the summer residence at Jehol, outside the Great Wall of China, where Earl Macartney was received by the grandson of the founder in 1793. The temple is built in the style of the famous palace-temple of Potala at Lassa, the residence of the Dalai Lama. But the resemblance is only superficial; deceptive as it may be when seen at a distance from one of the pavilions in the Imperial Park, on closer inspection the apparently storied walls prove to be a mere shell, with doors and windows all unperforated. The temple buildings erected upon the hill behind, the double roofs of which appear above the walls in the picture, are

really planned in the conventional lines of the t'ing and finished after the ordinary canons of Chinese architecture.

The picturesque stone structure illustrated in plate XVII, which is commonly called "Wu T'a Ssŭ," or the "Five-Towered Temple," is situated 2 miles west of Peking. It is said to be a copy of the ancient Indian Buddhist Temple of Buddhagaya, as explained in the following sketch of its history. In the early part of the reign of Yung Lo (1403–1424) a Hindu sramana of high degree named Pandita came to Peking and was given an audience by the Emperor, to whom he presented golden images of the five Buddhas, and a model in stone of the diamond throne, the vajrasana of the Hindus, the chin kang pao tso of the Chinese, being the name of the memorial temple erected on the spot where Sakyamuni attained his Buddhahood, which has recently been restored under British auspices. The Emperor appointed him state hierarch, conferred on him a gold seal, and fitted up for him as a residence the "True Bodhi" temple in the west of Peking, which had been founded during the preceding Mongol dynasty, promising at the same time to erect there a reproduction in stone of the model temple which he had brought with him, as a shrine for the sacred images.

The new temple was not, however, finished and dedicated till the eleventh month of the cyclical year kuei ssŭ (1473), of the reign of Ch'êng Hua, according to the marble stele set up beside it, which was inscribed by the emperor on the occasion. This states that in dimensions as well as in every detail it was an exact reproduction of the celebrated diamond throne of Central India. The temple is surrounded by a carved stone railing of Indian design, which is hidden by the wall in the picture, and which is surmounted by a stone fencing. The body of the temple, about 50 feet high, is square and of solid construction, composed of 5 tiers of stones carved with Buddhas seated in niches. Inside the arched doorway, right and left, are two staircases piercing the solid stonework and leading to the flat platform above, which displays in prominent relief a pair of Buddha's footprints and an infinite variety of symbols and Sanscrit letters strange to Chinese architecture. Within the five pagodas of Indian form, the central one larger than the rest, which are posed on the platform, the golden Buddhas brought from India are said to be enshrined, while their figures are repeated in stone and sunk in niches on the four sides of the walls outside each pagoda. For a description of the original temple reference may be made to Gen. Sir A. Cunningham's book, Mahabodhi, or the Great Buddhist Temple under the Bodhi Tree at Buddha-Gaya, London, 1892.

Taoist temples are built upon the same general plan as the temples dedicated to the Buddhist cult. The adherents of Lao Tzŭ have borrowed from the Buddhist bonzes the interior decoration of their sacred

halls, as well as the plastic representation of divinities, the worship of idols, and many of their ritual ceremonies. The Buddhist triad is replaced by an imposing triad of supreme deities called Shang Ti, who preside over the jade paradise of the Taoist heavens; statues of Lao Tzŭ and of the 8 immortals, called Pa Hsien, are posed in prominent places; and there are separate shrines for the 3 star gods of happiness, rank, and longevity, and for a multitude of lesser lights of the faith whose name is legion. The sacrificial vases, candlesticks, and incense burners, as well as the other ritual surroundings, bear distinctive Taoist symbols and emblems.

This slight sketch of Chinese architecture may be closed by a brief reference to Mohammedanism, which counts in China some 25,000,000 adherents, so that the emperor rules as many Muslim subjects as the British raj, about as many as the Sultan of Turkey and Shah of Persia together. There are about 20,000 Muslim families in Peking, with 11 mosques. Many of their shops and eating houses are marked with the sign of the crescent, and they have almost a monopoly of certain trades, including drivers of carts and pack mules, horse dealers, butchers, and public bath keepers. Every large city has its mosque, the Chinese name of which, Li Pai Ssŭ, or "temple of ritual worship," has been generally adopted by Protestant missionaries for their churches. The most ancient Chinese mosque is that of the "Sacred Souvenir" at Canton, which is said to have been founded by Saad-ibn-abu-Waccas, maternal uncle of Mohammed, who is supposed to have come to Canton to preach Islamism. This mosque was certainly in existence in the ninth century, when there was an Arabian colony in Canton. It was burned down in 1341, rebuilt soon after, and again thoroughly restored in 1699.

Chinese mosques resemble Buddhist temples in the fact that there is nothing in their exterior to indicate the foreign origin of the religion to which they belong. They are of Chinese style throughout; with the exception of lines of verses from the Koran written on the interior walls in Arabic script in the intervals of intricate scrolls of the usual Muslim formula, which form the only motives of decoration. The main building is divided into five naves by three rows of wooden pillars, the Mirhab, or wang-yu-lo, being at the end of the central nave. The general impression, on entering, is one of severe simplicity, contrasting strongly with the interior of a Buddhist or Taoist temple full of gilded images and embroidered hangings. The only furniture is one broad table of wood, carved in ordinary Chinese style, near the entrance, on which is posed on a pedestal the inevitable imperial tablet with the inscription "Wan sui wan wan sui" (a myriad years, a myriad, myriad years), which is officially prescribed for every temple, no matter what the faith, as a pledge of the loyalty of the worshippers. An incense-burning apparatus

in bronze of three pieces—the conventional "Set of Three" (San Shih), composed of a tripod urn, a round box with cover, and a vase to hold tools, all chased with Arabic scrolls—usually stands on the same table.

One of these Mohammedan incense burners is illustrated in plate XVIII. It is of cast bronze, shaped as a shallow bowl, with two monster-head handles, standing on three feet, also ornamented with masks of monsters. The sides, encircled above and below by rows of bosses suggestive of rivets, are engraved in two panels with foliated edges with Muslim inscriptions in debased Arabic, executed in relief on a punched ground. It is marked inside with two dragons inclosing the seal "Ta Ming Hsüan Tê nien chih," i. e ., made in the reign of Hsüan Tê (A. D. 1426–1435) of the great Ming dynasty. On the base, underneath, is another seal mark inscribed "Nui t'an chiao shê," i. e., for tutelary worship at the inner altar.

In the same courtyard as the mosque there are side buildings which serve as cloisters for the mullahs and the other resident officials, including usually a school where young Muslims are taught the elements of their religion from books printed in Chinese Turkistan, where the natives are all Mohammedans. There is, as a general rule, no minaret in Chinese mosques; the muezzin calls out the time of prayer from the entrance gateway. A half-ruined gateway of unusual height is illustrated in plate XIX. It belongs to a mosque built close outside the palace wall, within the city of Peking, by the Emperor Ch'ien Lung, for the benefit of a favorite concubine, a princess of the old royal line of Kashgaria, so that she might hear the call to prayer from a pavilion built for her, just opposite, on a hillock inside the wall of the prohibited palace. The Emperor tells the story himself on a marble stele erected by him in the precincts of the mosque with a triangular inscription, engraved in three scripts, Manchu, Chinese, and Turki, which has been translated in the Journal Asiatique by Monsieur Devéria.

FIVE-TOWERED TEMPLE, WU T'A SSU, NEAR PEKING. COPY OF MAHABODHI AT BUDDHA-GAYA. FIFTEENTH CENTURY.

BRONZE INCENSE BURNER, HSIANG LU. MOHAMMEDAN SCROLLS. MARK, HSUAN TÊ (1426-1435).

Height 15 inches, width 12¼ inches.

RUINED GATEWAY OF A MOSQUE, IMPERIAL CITY, PEKING.
EIGHTEENTH CENTURY.

PEWTER AND THE REVIVAL OF ITS USE.[a]

By Arthur Lasenby Liberty.

Taking first a wide survey of the whole subject, it will be remembered that the advantages of using an alloy in the working of metals appear to have been known and appreciated at a most remote period in the history of the human race, and that not only does such process combine the different excellencies of the two or more metals used, but the cohesion and consequent strength of the alloy is generally found greater than either of the metals considered separately, instead of, as might be supposed, resulting in the exact mean strength of the two or more metals employed. It is considered most probable, too, I believe, that the first discovery of metals was due to the accidental presence of ore in the stones used in primitive hearths and fireplaces, and that, consequently, the more readily fusible metals, such as copper, tin, and lead, were those first known, and of these, copper being the most widely diffused, is supposed to be the first metal used by man. Copper is, however, rather difficult to cast, and it must have been one of the most notable discoveries made by our primeval forefathers, that by a small admixture of tin an alloy was produced that could be easily cast, was capable of being finished to a smooth surface with sandstone or a file, and was very much harder than the original copper itself. Weapons and instruments made of this alloy—that is to say, of bronze—are, therefore, as is well known, characteristic of the early stages of civilization—the termination of the stone age showing occasional evidence of the use of pure copper. In later, as well as probably in prehistoric times, large quantities of the red metal copper were obtained from Cyprus (whence is probably due its modern name). While almost as far back as 4000 B. C., according to Mr. Flinders Petrie, the Egyptians are said to have worked copper mines in the peninsula of Sinai for the production of bronze. But the question, I believe, is still an open one as to where the ancients derived their supplies of tin. Tin, however, is mentioned among the

[a] Address before the Applied Art Section of the Society for the Encouragement of Arts, Manufactures, and Commerce, London, May 17, 1904. Reprinted from the Journal of the Society of Arts, June 10, 1904.

spoils taken from the Midianites, and it has been conjectured that it was mined in some district of Central Asia, because it is also claimed to have been known (though where obtained is not clear) at an equally early date in China, and I believe, also, in Hindustan.

At a later date, but still before the Phœnicians had sailed beyond the pillars of Hercules, tin was unquestionably shipped from Tartessus in the south of Spain, a locality generally identified as the Tarshish of the book of Ezekiel. Still later, as we all know, the same enterprising navigators traded for tin to Cornwall and Devon, the Cornish peninsula, indeed, being identified by the Greeks solely with that metal, and named by them "Cassiterides," the land of tin, a title which, in view of the continuance and richness in the supply of this metal, it might justifiably have retained to days within living memory. Bronze being therefore the earliest known alloy, it may, perhaps, be permissible to suppose that the invention of pewter was due to an accidental reversal of the bronze-making process—that is to say, a small quantity of copper being mixed with a large proportion of tin. Be this as it may, such an alloy was subsequently discovered and found to possess much greater toughness and malleability than the pure white metal, and proved not to be affected by the acid of wine or vinegar (as is bronze). It was, too, both in appearance and durability, to a certain extent a passable substitute for the rarer metal, silver. It has even been suggested as probable that the "tin" mentioned by Homer in his description of the shield of Achilles, the "tin" statue of Daedalus referred to by Aristotle, and other similar artistic works described by ancient writers, was in reality a kind of pewter, since pure tin is very brittle, especially at certain temperatures, and not at all adaptable for working easily with the hammer.

Plautus mentions pewter dishes as being used at a banquet, and Galen recommends the keeping of antidotes and other drugs in vessels of glass, silver, or pewter. It would exceed the bounds of this paper, however, to attempt to follow the not too easily traceable history of pewter through the classic to the middle ages; although I wish to call passing attention to some illustrations of pewter vessels from the extremely interesting collection of Romano-British pewter now in the British Museum. It will suffice to mention that the craft existed in the early days of Greece and Rome, was never absolutely lost, even in the dark ages, and was practiced, more or less, in Saxon and Norman times in England as well as on the Continent. In mediæval days the principal patrons were, of course, the church, especially the monasteries. But I believe no specimens of this period are now extant. And this recalls the unfortunate fact that the facility with which pewter can be remelted and cast has been always fatal to the survival of ancient examples, for whenever pewter objects became badly worn or bruised it was always customary to send them

to the melting pot to be remolded. All the ancient pewter utensils and vessels which have come down to us, are, therefore, those only which could not readily receive damage.

As Viollet-le-Duc points out, pewter in mediaeval days was the material in universal use for the tables and sideboards of the middle and upper classes, silver plate appearing only in the royal palaces and in the dwellings of the highest nobles, and then probably in very limited quantities at the upper table on the dais. The peasant and the artisan, it will be remembered, used dishes and platters of wood, or, as it was called, "treen," from whence we are told comes our word "trencher."

THE PEWTERERS' CRAFT IN ENGLAND.

The manufacture of pewter, therefore, during long centuries was a most important industry, the quantity produced was enormous, and from the eighth century, when the mines of Spain, the only others which appear to have been of importance, had ceased to be available in consequence of the Moorish conquest, down to the discovery and working of the tin mines at Perak, our own country possessed a practical monopoly of the metal, for the tin derived from Bohemian mines discovered in the thirteenth century was comparatively small in quantity. I would suggest, therefore, that the major portion of the pewter made in Europe from the days of Roman civilization down to the latter part of the last century, was made from English tin; that is to say, down to the time when the general use of pewter was supplanted by the introduction of earthenware and glass; just as in the same way pewter itself had previously supplanted the general use of wooden ware. Assuming, then, the patriotic postulate that Great Britain so long held a practical monopoly in the supply of tin to the world's markets to be correct, I purpose referring in detail to the tin and pewter industries mainly, in this country only, and the more particularly as they seem to be sufficiently typical of the like industries elsewhere.

Mr. Welch tells us that by far the larger portion of the tin produced in England was absorbed between the Pewterers' Company of London and members of the same craft throughout the country. Bapst says that Bruges was the principal mart for British tin on the continent, and that it was supplied thence to the whole of the north and west of Europe. The tin mines are still called "stannaries" (from stannum, the Latin word for tin), and were at a very early period granted privileges and placed under regulations by the Crown. According to Camden, King John, who was Earl of Cornwall before his accession to the throne, gave the earldom, with its privileges, to his second son, Richard, who derived from the stannaries in royalty and fines an annual income of 200 marks, equal to about £20,000 of

our money. "Great revenues," says the foregoing authority, "were drawn from the same source by the Dukes of Cornwall (beginning with the Black Prince); the royalty in the Middle Ages being as much as 40s. (equal to over £30 of our money), for every thousand pounds weight of dressed tin brought into the market." All tin had to be brought to certain specified towns to pass the Stannary courts, and there be stamped with the mark of the Duchy and the dues paid. After which, according to Mr. Welch, the guilds of the mines could sell to whom they pleased, except that the King or the duke had the right of preemption at the market price. Later the Pewterers' Company of London obtained the right to purchase one-fourth of all the tin brought to London for sale. The tin miners and, in fact, all connected with the industry at the mines were subject only to their own stannary courts of law (except in capital cases), and had even their own prison at their headquarters at Lostwithiel. Generally speaking, the royalties and dues were farmed. It must be understood, too, that whereas in other parts of the United Kingdom only the gold and silver were reserved to the Crown, the tin of Cornwall and Devon has always been the property of the King whoever may have been the owner of the soil. It is a peculiar institution, therefore, of Cornwall and Devon that, on lands not under cultivation, anyone on complying with the necessary formalities can mine for tin on condition of paying the royal dues and one-fifteenth to the landowner. The last assembly of the stannaries was held in 1752.

In common with all the other crafts carried on in the towns, that of the pewterer was doubtless bound by some sort of fraternity or association in the early middle ages, but the first formal institution of a guild was in the reign of Edward III, A. D. 1348. The ordinances for the government of this body were drawn up by its members and submitted to the lord mayor and aldermen, and by them approved. The records of the Craft of Pewterers thus commenced are more or less continuous from the establishment of the still existing Pewterers' Company in the reign of Edward IV, A. D. 1473, and are the material from which Mr. Welch has compiled his interesting history of the Pewterers' Company, published two years ago. These records, too, are not only interesting as a history of the guild, but afford a mass of information as to its relations to the general body of the citizens and the government of London in medieval times. The earliest rules for controlling the craft provide for the assay of all wares and for experts superintending the same. Anyone selling pewter before it passed the proper test, was condemned to forfeit the goods. Still, contrary to the general belief as to custom in such matters, the regulations do not appear to limit the ranks of the workmen to those who duly passed through a formal apprenticeship, but stipulated that either such (or otherwise competent men) should be employed. An

FIG. 1.—CANDLESTICK WITH HOLLOW COLUMN ADAPTABLE FOR ELECTRIC LIGHT. (MODERN GERMAN.)

FIG. 2.—CARD TRAY WITH CONCENTRIC ORNAMENT IN LOW RELIEF. (MODERN ENGLISH.)

FIG. 1.—BISCUIT BOX.
(MODERN GERMAN.)

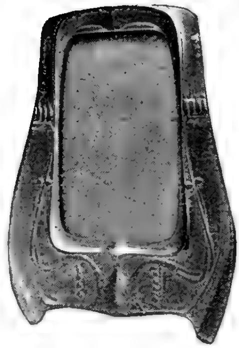


FIG. 2.—FRAME FOR PHOTOGRAPH.
(MODERN GERMAN.)

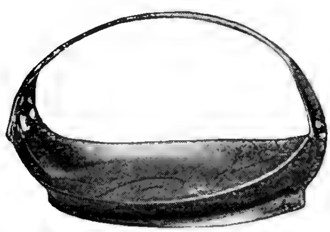


FIG. 3.—CAKE OR FRUIT BASKET. (MODERN GERMAN.)

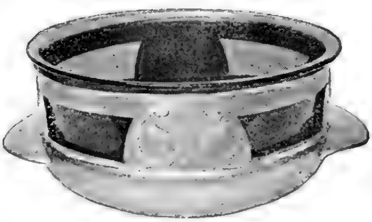


FIG. 4.—FRAME WITH EAR HANDLES FOR GLASS FLOWER BOWL. (MODERN ENGLISH.)

FIG 5.—TRAY AND LID FOR GLASS BUTTER BOWL.

incidental commentary on the primitive lighting arrangements of the time is contained in the rule that no work is to be done at night, and it is easy to understand that work produced under the flare of a rough flambeau, or, on the other hand, by the meager light of a tallow candle, was not likely to enhance the reputation of the craft. As just mentioned, the penalties for bad workmanship, or for inferior quality of metal, were forfeiture of the articles and fines; suspension from membership was also inflicted in some cases, and for very bad or often-repeated offenses, expulsion. This last practically amounted almost to outlawry, for unless the offending member were readmitted it deprived him of his livelihood; since, if not a member, he could neither buy nor sell nor be employed. No master was to employ a workman without a character from the last employer, nor was he, under any circumstances, to entice away another's workman.

The qualities of pewter were also prescribed to prevent adulteration and inferior quality of metal being used. These regulations were always strictly enforced, and the control of the guild over the trade was fostered by the Crown and Parliament for many ages, its effect being to set up a very high standard of quality, both of material and workmanship, and thus maintain the excellent reputation of English pewter, besides insisting on a code of commercial morality which could not but have a great effect on the members as citizens.

The craft at this time consisted of three grades: The livery, or brethren, from whom were elected the wardens and other officers of the craft; the freemen, or yeomanry, members who had obtained license to set up in business for themselves, and the covenant men (journeymen) and apprentices. One of the rules most strictly enforced was that no members were allowed to go to law with one another, all disputes having to be submitted for decision to the warden and craft, thus keeping in view the idea of brotherhood in the society.

These ordinances, it must be remembered, were promulgated by the body called the Craft of Pewterers; and although there was doubtless a fraternity of workmen prior to this, and probably dating from quite early times, the regulations in question, having now been ratified by the lawful government of the city, first put the control of the trade on a legitimate basis. It must also be remarked that such control, though absolute, was not despotic, an appeal always lying to the lord mayor and aldermen in cases of injustice and oppression. In fact, not only under the Craft of Pewterers, but afterwards under the duly chartered Pewterers' Company, the city fathers often interfered in case of an arbitrary exercise of power, without any appeal to them having been lodged. With all the faults of the paternal government of trade during the middle ages the spirit of the guilds was distinctly democratic, and such regula-

tions were recognized as existing for the benefit of all. The records show, indeed, in a very striking manner the absence of privilege and mere influence, the very master or wardens of the company, in their capacity of craftsmen and dealers, sometimes falling under its discipline.

During the hundred and thirty years which elapsed between the formation of the old body of the Craft of Pewterers and the incorporation of the Pewterers' Company the guild had no hall, but rented premises for their feasts and business meetings from the House of the Austin Friars. Special religious services were observed by the brethren at Christmas, Easter, and the Feast of the Assumption, generally at the Church of the Grey Friars. The expansion of trade and the consequent increase of wealth and influence of the city of London generally during the fifteenth century doubtless excited the ambition of the craft for incorporation as a regular city company, and after delays, probably due to the disturbed state of the government through the Wars of the Roses, a charter was granted by King Edward IV in 1473 creating the existing Pewterers' Company. This charter is still preserved in the archives of the guild, and is a beautifully written and illuminated document in Latin. The powers already de facto possessed by the craft were by this instrument confirmed and extended, one of the most valuable new concessions being that of the right of search for inferior goods and metal below the proper standard of purity. This right not only was to extend over London and its suburbs, but over the whole country, and all provincial mayors and sheriffs were enjoined to assist the company's officers in the work. All such inferior goods or metal was to be seized and sold, the proceeds to be divided between the company and the Crown. These searches, besides fulfilling the primary object of protecting the trade against fraud and bad work, had the result of greatly strengthening the company's importance, and consequently attracting numbers of provincial pewterers into its ranks. The officers of the company who undertook the country searches were accustomed to entertain the provincial master pewterers while on circuit at the expense of the guild, and the country members when in town also enjoyed the hospitality of the city. Hawking goods by peddlers at fairs or markets was strictly forbidden, under pain of fines and confiscation of the articles, the shopkeepers, who of course were at the charge of rent, taxes, and other dues, claiming and enforcing the privilege of keeping the trade in their own hands.

Soon after the establishment of the company and its consequent expansion the need began to be felt for a hall of its own, and accordingly a site was found for the same in Lime street, where the present hall now stands. From very early times it had been the custom for

the wardens to purchase large quantities of tin from the stannaries in bulk and to retail the same at a small profit to the members, a plan doubtless advantageous to all parties, as the profit was applied to the payment of the general expenses of the guild. During the building of the hall, however, which necessarily caused a great drain on their resources, this practice was discontinued, but was resumed on the completion of the work. Part of the site was occupied by tenements built at the same time by the company, and the rents of these and sums received for the hire of the hall for wedding parties appear to have materially increased its income.

In 1504 a statute of the Parliament of King Henry VII abrogated the right of any guild or company to make ordinances without the same having received the assent of the chancellor, treasurer, or other officers of the realm, and at the same time rendered illegal the particular by-law which forbade members of such a fraternity from suing one another in the King's courts. In the same Parliament an act was passed in the interest of the pewterers to suppress hawking by peddlers, the adulteration of metal, and the use of false scales and weights. This statute was confirmed in the fourth year of the reign of Henry VIII.

In accordance with the first-named act of 1504, the ordinances of the company were, after eighteen years' delay, submitted to the King for confirmation in 1522, and duly assented to after the usual presents and gratifications to courtiers and ministers. About this time the importation of foreign pewter was seriously competing with the English trade, and after a considerable amount of lobbying and bribery in Parliament an act was passed in 1533 totally prohibiting the importation of foreign pewter, any so smuggled to be forfeited, together with a fine to the amount of the value. The right of search was again confirmed, and no foreigner was to be employed in the trade under any circumstances and under heavy penalties, and no person of foreign birth to be apprenticed. It was also forbidden for an Englishman to exercise the craft anywhere beyond sea, and thereby teach it to foreigners. Hawking was again forbidden, even when exercised by duly qualified pewterers, none to be sold except in a shop attached to a dwelling house, or in open fairs and markets. It is curious to note here that the Pewterers' Company republished these acts in a book form so late as 1741.

As an instance of the tight hold kept by the company on its members, it may be mentioned that at a court held in March, 1559, it was decreed that Robert West should bring his wife upon Friday next to " reconcile herself to Mr. Cacher and others of the company for her naughty misdemeanor of her tongue toward them."

No man was allowed to set up in business without first submitting to the master and wardens a specimen of his work. In case of dis-

putes between members of the guild, it was often decided that the one of the litigants held to be in the wrong should invite the other with his wife to supper, "and then to be merry together and so to be lovers and friends henceforth."

A very high standard of commercial morality was enforced. For instance, no pewterer was allowed, under a penalty of a fine of 20s. (probably equal to £10 of our money) to say to a prospective customer that his goods were superior in quality to those of others.

The following is a specimen of the amenities obtaining at the time between the English and those of the sister kingdom: "Thomas Wolshire shall pay for his opprobrious words toward Richard Scot, saying 'He played the Scot's part and had the Scot's heart,' 16d." Members had to attend the funerals of their confrères on pain of fine, unless they had a reasonable excuse.

Not only apprentices, but unmarried journeymen lived in their master's house and accompanied him to church on Sundays. They were not to absent themselves until after the afternoon service, when they were permitted to amuse themselves with shooting at the butts and dancing. On the other hand, the company was resolute to defend the rights of members, and once, for example, forbade any of the craft from serving any persons belonging to the Saddlers' Company until a claim against it by a pewterer had been satisfied. Adulteration of metal, as before mentioned, was severely punished, sometimes by expulsion, the culprit being described as acting contrary to his oath and "like no trewe pewterer and to the great slaundre of all the pewterers in London." Sometimes on giving an undertaking and a surety not to repeat the offense he was received back, but was made to pay a substantial fine. In cases when the offense was not very flagrant the punishment was to make the culprit change his mark, this being equivalent to a fine, in consequence of the loss of time and the expense of re-marking his stock and obliterating his old mark.

The statute of apprentices having been passed in 1563, the company, in 1564, issued an ordinance that each member of the livery should be allowed to take one apprentice, the master and wardens might have three, but only on condition that they employed two journeymen. Misbehaving apprentices were sometimes sentenced to be whipped in the hall. No member was allowed to sell old pewter bought secondhand, and no pewterer was to act as scullion even for the lord mayor himself, nor to repair or clean pewter except at his own workshop—a suggestive rule for maintaining the dignity of the craft. Gilding pewter was strictly forbidden, except when given as a present to friends. To insure proper registration, the members of the livery were accustomed to set up their marks in the hall.

It was a custom coexistent with the company for members to be enrolled who were not pewterers. An instance that may be given is that of one Isaac Tucker, who, in the year 1556, was admitted on the recommendation of "Sir Water Rawghley" (sic) on payment of £10, half of the usual fee payable by such members. It is expressly stated that this was done out of respect to "Sir Water," and for no other reason.

No journeyman was allowed to trade on his own account, but must obtain the permit of the company and register his mark or "touch," as it was technically called, and if a tradesman left London and afterwards returned he had to pay his dues for permission to start a second time. No tin was to be exported, except after having passed through the pewterer's hands—that is, in bars or made into pewter ingots.

In the last year of Elizabeth's reign it was forbidden to allow country pewterers and others to enter shops where London men were at work, "whereby they come to great light of further knowledge:" in other words, were finding out trade secrets. The monopolies granted by James I to the farmers of tin had a very prejudicial effect on the industry, and the company accordingly petitioned several times against the practice, which, after a time, was modified by the King. The sixteenth and early part of the seventeenth century must have been the palmy days of the pewter trade. The prosperity of the middle class brought substantial comfort into the homes of the artisan and the laborer, and every fairly well-to-do citizen, among other belongings, seems to have made a point of possessing his "garnish" of pewter, while even the thrifty workman and peasant had a modest quantity. A "garnish," I may here recall, consisted of 12 plates, 12 smaller platters, and 12 dishes. At this period, also, large quantities of pewter were kept in stock by members of the trade for hire to the nobility and gentry as well as to public bodies for banquets and other festivities, the pewterers often helping one another with loans when a great demand was made on their resources.

DECLINE OF THE INDUSTRY.

The causes of the decline of the pewter manufacture in England, as on the Continent, were mainly, as before stated, the competition of cheap earthenware for table and other domestic use, followed by deterioration of quality and design, and consequent loss of influence on the part of the English Pewterers' Company. The guild had for centuries maintained, by rigid enactments, the high quality of English pewter, both for home consumption and for export, and these enactments were enormously aided in their enforcements by the company's right of search. During the troubles of the great civil war, however,

this right fell almost into desuetude, and after the restoration the company found that it is much easier to maintain a privilege than to reimpose one when once practically abrogated. The right of search was felt to be unsuited to the spirit of even that age, and the company never succeeded in getting it legally recognized again. Possibly, as has been suggested, the authorities were indisposed to bring the question before the courts of law; as, in the case of an adverse decision, the right would definitely cease to exist, whereas by leaving the matter unsettled it might be once more established, should a favorable opportunity arise. It is probable also that the practice which we have seen had existed from early times, of admitting into the fellowship of the guild members who were not connected with the craft, became more and more common, until many of the influential so-called "pewterers" had ceased to possess any real business interest in the trade, with the inevitable result that the main object of the existence of the company was neglected.

Efforts, however, were made from time to time to revive the declining industry, but slowly and surely the products of the potteries ousted the plates, dishes, and vessels of pewter, whilst the art of plating inferior metals with silver displaced the old pewter dish covers, cruets, salt cellars, drinking cups, and the like, until at last even in the village inns and hostelries the electroplated tankards displaced the pewter pot. This last fact is significant, since good judges of malt liquor never lost the tradition that ale or stout was of better flavor when drunk from what was called "its native pewter." Thus the once flourishing craft of the pewterer degenerated to the production of some few mere utilities, such as lavatory fittings, public house bar appliances, and plumbers' requisites. Although exclusive reference has been made to English pewter, we must not forget that the pewterers' craft embraced Scotland, notably Edinburgh, as demonstrated by the "Tappit Hen" and "Christening Tankard," which examples by the courtesy of Mr. Walter Churcher are, with others from his collection, here for our inspection this evening.

MARKS.

Great numbers of old touches or makers' marks have come down to us, but it is, unfortunately, the fact that no register of them exists, and unless the name is mentioned they are, therefore, difficult to identify. Much interesting information from the collector's point of view has been written on the subject of marks, but it will suffice for the purpose of this paper to say that no piece of pewter was allowed to be sold without a mark, and that this rule extended to the pewter mountings on stone jugs and tankards; and it is thought probable that the crowned "Rose" mark was in some measure the official "touch" of the Pewterers' Company, being one of their armorials,

FIG. 1.—LIQUEUR SET AND TRAY, WITH FLORAL ORNAMENT IN LOW RELIEF (MODERN GERMAN.)

FIG. 2.—TWO-HANDLED VASE. (MODERN GERMAN.)

FIG. 3.—HOT-WATER JUG, WITH ORNAMENT IN LOW RELIEF. (MODERN ENGLISH.)

FIG. 1.—COFFEE POT, SPOUT MADE IN ONE PIECE WITH THE BODY. (MODERN GERMAN.)

FIG. 2.—GLASS CLARET JUG, WITH METAL MOUNTINGS. (MODERN ENGLISH.)

FIG. 3.—BEER TANKARD, WITH HANDLE. (MODERN ENGLISH.)

while the double "f" was a penal mark sometimes affixed to the work of a member who had been found guilty of malpractices, and signifying, as it did, false, the result commonly was his being obliged to join the ranks of the journeymen of the craft.

ALLOYS.

And now I must refer to the alloys and the process of actual manufacture. It is still questionable, I believe, what were the precise alloys and the relative proportions used in the manufacture of ancient pewter; and, indeed, down to our own day the word "pewter" has an elastic meaning. I gather, however, that some among the old examples show a large admixture of lead, as, for instance, a vase handle of the fourth century of our era, dug up in Rome, which, according to Bapst, was assayed in France early in the last century and found to contain about three-sevenths lead, without any trace of copper. This must, therefore, be considered as of very inferior quality. By way of explanation it has been suggested, indeed, that tin procured with difficulty from a remote and barbarous region was almost as dear as silver, and that this may account for the low grade of pewter being in use in Rome. On the other hand, however, Mr. Gowland's analysis of varying examples of Roman pewter show that the question of cost was by no means invariably considered. His results give for what he terms "typical" Roman pewter: 72.36 tin to 26.90 lead, and 70.58 tin to 27.62 lead; that is, to put it roughly, three parts tin and one part lead.

According to Mr. Welch, in the ordinances of the old English craft of pewterers two qualities of pewter are described, the first of tin with a small admixture (supposed to be about 5 per cent) of what is called "kettle brass," otherwise known as "peak" metal, the peak metal being a compound of copper with some other metal not definitely ascertained, and probably always kept a mystery of the guild. The second quality was originally called "vessel of tin," being a compound of tin and lead in the proportion of 1 hundredweight of tin to not exceeding 26 pounds of lead. This alloy was afterwards known as "lay," or lead, metal.

Some old pieces of the Elizabethan and Stuart periods were assayed two years ago by my friend, Mr. Haseler, when conducting some experiments on behalf of Liberty & Co., and besides tin he found them to consist of small quantities of copper, with traces of antimony, the latter probably being added for the hardening and cleansing of the other metals. These pieces were of what is known as the old first quality of pewter. We have seen that the craft always guarded most jealously the good reputation which the English pewter held, and that it included the keeping up of the requisite standard of purity in the metal. It was for this purpose, indeed,

that the Pewterers' Company possessed and exercised their peculiar powers. Thus, as has been noted, all tin brought to London was liable to be assayed by the company's inspector before being sold, and it could be seized and forfeited if of inferior quality, no matter to whom it might belong. It was also ordered (in 1438) that all articles (in accord with a published list) should be of a certain standard weight, thus insuring to purchasers a definite quantity of the metal. This was doubtless an excellent rule to prevent fraud when recasting was so constantly resorted to in order to make good the constant wear and tear to which pewter articles were liable at a time when they were used for practically all domestic purposes. Thus, it was a definite rule that "chargeours" of the largest size were to weigh three-fourths hundredweight per dozen, i. e., 7 pounds each, and small "bolles" 13 pounds per dozen.

In the present day and of late years many experiments have been made and various modifications have been tried in the composition of pewter, nearly every manufacturer having his own particular formula. For the production of modern pewter goods aspiring to be classed as artistic in design, the inferior alloy containing lead is discarded altogether (except by the Japanese in the manufacture of their antimony ware). And to avoid as far as possible the use of copper, which some consider to have a bad effect on the color, tin is nowadays alloyed in the proportion of about 5 per cent of antimony, or bismuth, or both. An excess of copper imparts a brownish tint, whilst the use of lead (always be it remembered the alloy of the so-called second quality pewter) imparts the well-known gray color tone which, be it acknowledged, has for some of us a decided charm. Still, as we know, if lead is used beyond a certain proportion it renders the pewter dangerous for the use of liquors containing acids, such as beer, wine, vinegar, etc., by reason of the chemical action they set up, the excess lead producing poisonous oxides.

A series of experiments were made some years ago under the auspices of the French Government, which resulted in a law being passed prescribing the proportion of lead which may safely be used, and this was fixed for France at 16½ per cent. The old pewterers appear to have had one advantage over the modern in the fact that their lead nearly always contained a small percentage of silver, which (unfortunately for the pewter trade) science has enabled the modern smelters to extract. That is to say, the fascinating luster which many old pieces of pewter possess is generally ascribed to the presence of this small proportion of silver in alloy. Modern German pewter, as compared with modern English, contains a much larger proportion of antimony, with some bismuth, and gives out when bent or bitten (which the modern English does in a far less degree) the well-known distinguishing crackle or cri. Modern German pewter

is produced principally in Nuremburg, Crefeld, and Munich. The German alloys have, in my opinion, however, the disadvantage of being more brittle than those used in this country, and I refer particularly to those used by the company with which my own name is associated. The alloys used by it are, as before mentioned, the results of careful trials made by my friend, Mr. Haseler, a partner in and director of Liberty & Co.'s works at Birmingham. His endeavor has been to reproduce a metal similar, as far as possible, to the best of the old English pewter, and in point of solidity the new alloy is, I believe, unequaled. The exact constituents and proportions used are regarded as a trade secret by my colleagues, as is the case with the composition of the alloy used by our German friends, although both could, doubtless, be readily assayed.

MANUFACTURE.

Pewter work is either cast, spun, or hammered, and the methods of manufacture differ in no essential in the present day from those of the olden times. Most of the old pewter was cast in molds of brass, which were highly finished inside and fitted with great nicety. But specially prepared iron is preferred nowadays, as higher skill in the working of the more enduring metal has been attained. Pewter can be cast of any degree of thinness, and is turned out of the mold in a state requiring a minimum of work in the finishing process, apart from the inevitable polishing and soldering. In the active days of the Pewterers' Company the guild was accustomed to purchase and to have made to order a large number of molds, which were let out on hire to its members. The latter, of course, also possessed stocks of molds of their own, often held in shares by different tradesmen. The reason for this arrangement was the great expense of producing properly made molds, and by this means the expense was shared by members to mutual advantage. The elaborate pieces, incrusted with ornament in relief, produced on the Continent during the Renaissance, especially in the sixteenth century, were cast in a different way, i. e., in sand, and in sections afterwards soldered together. These pieces, being produced in small quantities, the cost of a metal mold would have been prohibitive, since even for plainer work it was necessary to spread the cost of a mold over a great number of articles. The articles being cast in sand, however, left a finely granulated surface, requiring a considerable amount of extra labor to finish them by polishing and chasing.

One of the most satisfactory pieces of old English pewter, and perhaps the example most frequently referred to, is a large dish in the South Kensington Museum, of which, by the courtesy of Sir Caspar Purdon Clarke, I have been enabled to bring a sketch here to-night.

It will be seen that it is engraved with the royal arms and a floral border of simple design, and bears an inscription dated 1662. The engraving on it is plainly but boldly executed, and has the great merit of obtaining that too often ignored quality, namely, suitability. But, as we have seen, the quality of English pewter, as far as regards the metal employed, was always unrivaled, and the strength and excellence of the workmanship was also equal to the best. In the department of design, however, we have nothing to show in old pewter to compare in elaboration with some of the pieces still existing, the work of continental craftsmen. I greatly prefer, however, the taste of our own workmen, who made their platters and bowls almost always plain (and, therefore, more easily cleaned), depending on the shapes alone for the good effect of the cups, tankards, and measures. The shapes of our old craftsmen's hollow ware are almost always excellent and generally far superior to the classical ewers and vessels produced by the Frenchmen of the Renaissance. Our rivals on the Continent, indeed, appear to have made the great mistake throughout of overelaboration (for pewter is essentially a homely metal), with the inevitable result of subordination of shape to ornament. Some of the ewers and other vessels made by Briot, who has been called the Cellini of the pewterers, are, however, dignified. in addition to being elaborate. But too many of the show pieces in the museums and private collections by German makers of the Renaissance period are both inferior in execution and absurdly overdone in decoration.

The solder used is still the hard solder of the middle ages, made of tin and lead, sometimes with a small proportion of bismuth, and when skillfully done the process insures not only mechanical adhesion, but forms an alloy of itself between the solder and the metals joined. The old pewterers strictly forbade the use of soft solder (i. e., solder with too much lead); and although handles of jugs, etc., and the ears of dishes were at one time soldered an ordinance made in the reign of Elizabeth decreed that in future they were to be cast in one piece. Modern hollow ware is often "spun," as it is technically called, very much in the same way as clay on a potter's wheel. The metal is forced into the shape required by a blunt steel tool onto a wooden "chuck," or block, of the shape of the vessel to be made, and much of the ornament is worked by hand with the hammer and chaser. Some pieces are entirely hammered up from the sheets of pewter, and therefore bear the impress of individuality to a more marked degree.

THE REVIVAL.

I now come to the concluding and the more practical side of my subject—the revival of the pewterer's craft as an art industry. And here I would again allude to the notable paper on pewter read by

Mr. Gardner ten years ago, and the interesting fact that no sooner had the echoes of his words of lamentation died away than the cloud which threatened extinction to the industry slowly lifted, and from that day the erstwhile moribund craft has been struggling back to life. Among the controlling influences tending toward this result a certain firm, whose name I need not mention, had, shortly after that time, adopted for designs in silver plate and jewelry the motif and lines of ancient Celtic ornament. The results proving fairly satisfactory, the question arose, Why not apply the like forms and designs to the manufacture of pewter? Thus, rightly or wrongly, the pioneers of the revival of Celtic ornament decided to work in pewter on somewhat parallel lines with silver, and came to the conclusion that nothing is produced by the silversmith which may not, as occasion arises, be made in pewter, but with the distinct proviso that any attempt to imitate the precious metal should be avoided. For pewter, however, only modifications of Celtic forms were used, and these were soon supplemented by floral and plant motives to which the distinguishing name of "Tudric" was given. This modest effort was, at all events, the first step toward the reawakening of the pewter industry, and up to the present it remains the only effort that has been made in England. It attained some commercial success, and, directly and indirectly, it has been the means of the revival, so far as a revival has at present progressed. But the ideal of modern English pewter, as conceived by its sponsors, aims at more than a commercial success—it aims at a high standard in design, a high standard in workmanship, and a high standard in the quality of the metal, and it strives to avoid overmodeling and overchasing. It would devote attention to shapes being properly adapted to the several purposes for which the objects are made, it would see that the constructive lines be graceful, well contrasted, and strong, and that ornament, when used at all, be used with restraint, and grow out of the general design. These excellent intentions, unfortunately, are not always carried out, for faulty and eccentric notes strike out from time to time. These, however, it is confidently believed, are mere accidents by the way, and will doubtless become less and less frequent. The Germans are, practically, the only Continental representatives of the modern pewter industry, and they, having observed the new note struck in England, appear to have seized upon the fact that a change in the fashion of their own wares was desirable. So, forthwith, they proceeded to produce what they conceived to be an improvement upon the English work, and translated it into the fantastic motif which it pleases our Continental friends to worship as l'art nouveau. Still, alongside the foolish and undesirable, it must in justice be admitted that the Germans have recently produced many original and pleasing designs in pewter. I allude, particularly

to the work of Messrs. J. P. Kayser & Sons, Messrs. Walters Scherf & Co., and Messrs. Lichtinger & Co. The present aim of the German pewterers seems to make for rather different results in certain details than with our designers, the ornament being made sharper and higher in relief, and the excess of antimony, or some similar alloy, used enables them to execute this kind of casting with great facility. As compared with goods made in this country the surface manipulation and finish of German goods is often more careful and satisfactory. On the other hand, our alloys are much less brittle, our work flatter and broader in treatment, and thus, it will, I think, be found that our designs and methods are more suitable to the capabilities of the metal, and are therefore better calculated to permanently advance the pewter industry.

As for the lines on which to advance, it should be remembered that for historic mansions and houses where the apartments are furnished after the style of the Renaissance, and wherever magnificence is fitting and desired, a rich and sumptuous array of costly silver plate is doubtless in harmony with its surroundings; but for the majority of households I venture to think that pewter is equally desirable for the many decorative adjuncts of refined and restful furnishing, and the more particularly as it can be obtained at modest cost. On this latter point we are continually being told that objects of art should not be regarded as luxuries, but should be easily attainable by rich and poor alike. Everything, therefore, which tends toward the production of useful and beautiful objects at prices within the reach of all classes should be welcomed. And herein, perchance, in these days of culture, are to be found the future possibilities of pewter, for its soft neutral tone and subdued luster harmonizes with any scheme of decorative coloring. Those, too, who object to the use of electroplate as an imitation of silver may be content to accept equally good forms in solid pewter in its place, while those who are already the fortunate possessors of treasures in pewter may contemplate with equanimity the advent of the burglar.

The manufacturer, however, realizes that as by a process of natural evolution pewter has ousted wood from the kitchen, so china in its turn has inevitably supplanted pewter. The fact must be squarely faced by him, therefore, that it is useless to reproduce the large majority of those many fascinating forms in old pewter, where the purposes which brought them into being are now attained by the substitution of other and more appropriate wares. For instance, however beautiful their form and patina, it would be absolutely useless to tempt a modern housewife to purchase pewter plates and vessels for tea and table use, now that spotless and dainty white

FIG. 1.—TRIPOD BOWL, TO HOLD GLASS DISH FOR FLOWERS. (MODERN ENGLISH.)

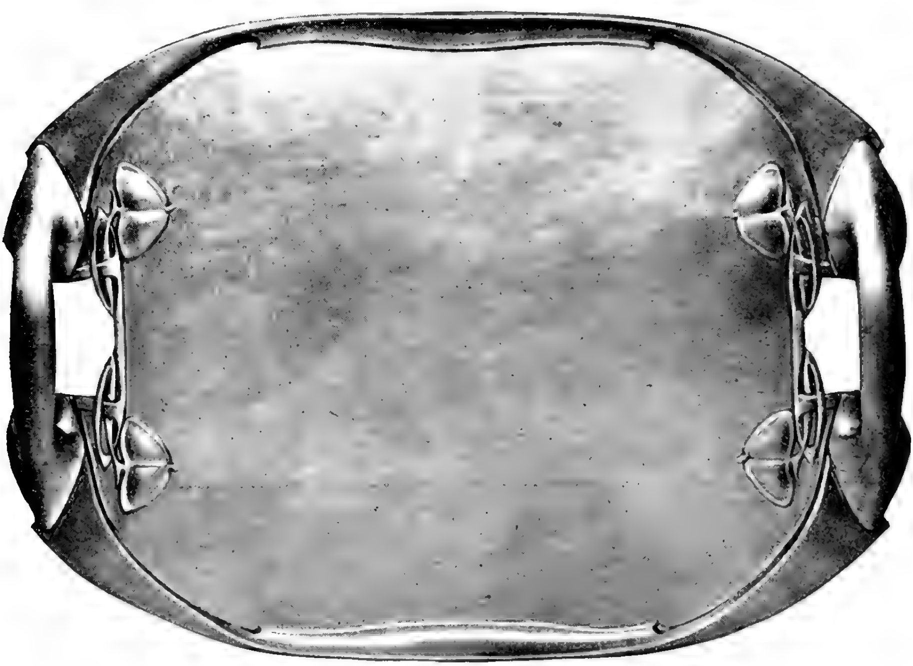


FIG. 2.—TRAY WITH GRIP HANDS. HOLLOW RIM GIVES ADDITIONAL STRENGTH. (MODERN ENGLISH.)

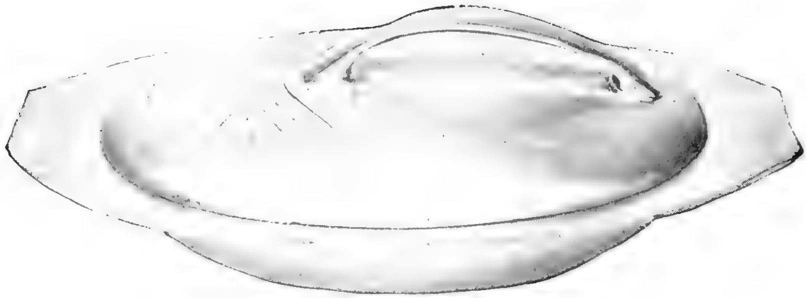


FIG. 1.—ENTRÉE DISH AND COVER, WITH ORNAMENT IN LOW RELIEF.
(MODERN ENGLISH.)

FIG. 2.—CIGAR BOX, WITH HAMMERED ORNAMENT SET WITH TURQUOISE.
(MODERN ENGLISH.)

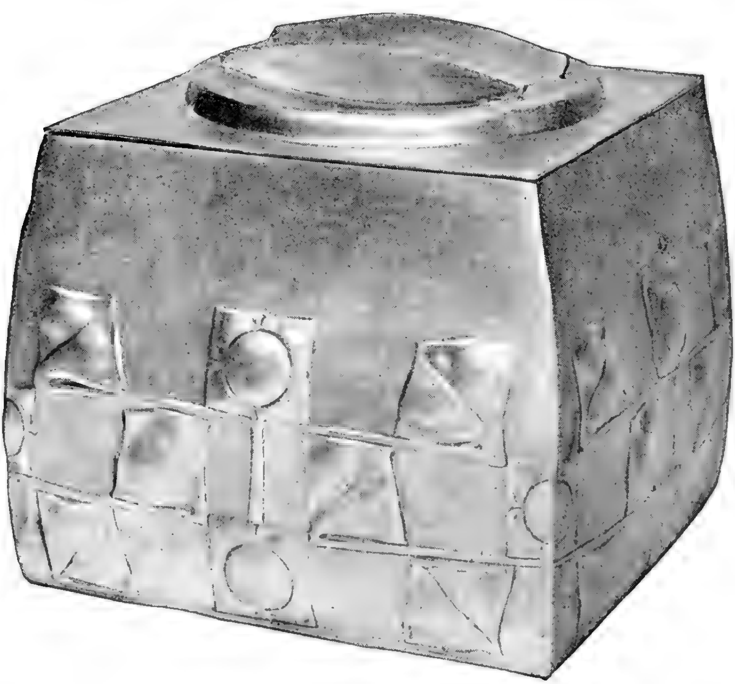


FIG. 3.—BISCUIT BOX, WITH HANDLES ON LID ARRANGED IN NOVEL FORM.
(MODERN ENGLISH.)

porcelain cups and dishes are obtainable at equal or less cost. A recent author tells us, indeed, that "it is a good thing to rub pewter over with a rag saturated with vaseline," but surely the process appeals to the palate as the reverse of appetizing, and is calculated further to emphasize the housewife's objection to pewter for culinary and table use. Then, too, besides the wares made for the service of food and other purposes requiring easy and perfect cleansing there is a quite considerable range of other things once made in pewter, which an altered state of conditions has rendered useless. These also are undesirable for the modern pewterer to reproduce. The author just quoted writes, however, in reference to some of them: "Among other instances of articles in pewter which have now unfortunately ceased to be made are snuffboxes, candle boxes, table fountains, and lavabos, or hanging washstands." Now, while sympathizing with collectors in regretting the disappearance of the good work of bygone days, it would be a more helpful attitude for the manufacturer to try to substitute useful objects for the useless ones. Instead of table fountains and candle boxes one might suggest the production of electroliers, jardinieres, and presentation caskets, challenge cups, card trays, and a host of et cæteras of the flower vase order. We have, indeed, an example of how a similar evolution was brought about by the Japanese metal workers, who, when they found that sword hilts and their inlaying were no longer required, transferred their attention to the invention of the cheap and clever antimony ware with which they have since flooded the European markets. And this antimony ware, be it remembered, is a branch of the pewterer's trade.

And now we come to the two questions which I have been working up to, i. e., (i) are the pewter wares now being made equal in quality and design to the average work of the best periods of bygone days? and (ii) what are the future prospects of pewter as an art industry?

The latest critic on this subject, the writer just referred to, has not one good word for modern pewter. He says:

> In striving to arrive at "art" pewter the manufacturers have produced the wrong kind of alloy. It is far too crude and white, and has a meretricious look, besides the fatal fault of almost looking like silver or electroplate. Another fault is that it is far too brittle and hard. There is no nice feeling in it; it is, unlike old pewter, hard and repulsive to the touch. Again, * * * satisfactory designs for pewter can not be extemporized by any designer, however cunning he may be at catching the public taste, so called, with a gaudy cretonne or a meaningless wall paper.

Happily, it is needless to add, there are many who hold more hopeful views on this subject, who consider a distinct advance has been made already, and who believe that there is good promise for the future.

DISCUSSION.

The chairman, in moving the vote of thanks to the author, said:

The charm of art was never so close, intimate, and grateful as when it was conferred on the familiar articles of utility about our hearths and homes. Its charm infinitely transcends in value the prices of the materials on which it is lavished, and can be equally imparted to the costliest substances—black ebony and white ivory, silver and gold, and precious stones—and to comparatively worthless substances—clay, iron, copper, tin, brass, and pewter, and ordinary woods—provided the artistic manipulation of them is sympathetically adapted to the distinguishing natural qualities—and the defects of the same—of these materials and to the uses the "objets d'art" fashioned of them are intended to fulfill. Just ten years ago Mr. J. Starkie Gardner gave us his scholarly paper (Journal, June 1, 1904) on "Pewter," and in it, as Mr. Lasenby Liberty has told us, expressed a regret that pewter had not shared up to that date in the great artistic renaissance of the reign of Queen Victoria. This observation was at once taken up by Kayser, and by Lichtinger in Germany, and in this country also by Mr. Lasenby Liberty, who for the past ten years has devoted himself, with the enthusiasm and resolution with which he pursues all his artistic enterprises, to the resuscitation of the ancient and once flourishing and famous British art of pewtery. Mr. Lasenby Liberty to-night has fully and clearly, and in the spirit of the most impartial criticism, told us of all that has been attempted and done in this respect by his firm, and from the specimens of their work placed before us and the illustrations of them in his lantern slides we can judge of the difficulties of the undertaking to which Mr. Lasenby Liberty has set himself as a labor of love and of the measure of success with which these difficulties have been overcome. What is required of all such articles is that while artistic they should never lose their utilitarian and homely character—that is, the character impressed upon them through untold generations of rough and ready domestic service. If this character is overlooked or ignored, or in any way blurred or masked, either in the form or the embellishments of these articles, if, indeed, it is not directly indicated and emphasized by their artistic treatment, the art elaborated on them has been wasted and is worthless, however unencumbered by purposeless conventionalities and unsignificant symbols or however original in conception and sincere in execution. The "summam alicui rei dare" to achieve here is directness, simplicty, and balance of form, the subordination of any ornamentation to the form and to the interpretation of its function, and the perfect adjustment of both form and ornamentation to the materials of which these articles are severally framed and to the human purposes they have to subserve. The decoration must not only be responsive to form and use, but as reticent as it is significant, and must avoid all excess. There must be no straining after originality, which, unless it comes of the rarest and richest genius, tends to languish under weak hands into nerveless and contemptible affectations and conceits and in strong ones to run riot in violent and offensive eccentricities. In France the contortionists of l'art nouveau have reached the basest artistic degradation in the studied pruriency of the nude decorative bronzettes with which the shop windows of all Europe have been crowded during the past three or four years. Compare them for a moment with the exquisite modeling and the purity of conception which is their animating soul, of the clay figurines of the coroplasts of ancient Tanagra and Thisbe, Cyme, and Myrina and you at once realize the gulf fixed between the inspirations of artistic genius and the diabolical subtleties of merely manipulative dexterity. There is, moreover, nothing new in this l'art nouveau. It is, in

its "motifs," the primitive art of all savage races, to which the highest mechanical perfection is found given in the art of ancient Egypt and in much of the ritual art of modern Japan, which Celtic art all but touched with spiritual perfection, and which in our time has been brought into vogue by the marvelous black and white drawings of Aubrey Beardsley, a man of undoubted genius, but who, it should always be remembered, received his artistic training as an architectural draftsman, and again by the seductive jewelry of Lalique and cameo cut glass of Gallé. But at its best it is not of true artistic inspiration, but an intellectually conceived and calculated mannerism, foredoomed in the hands of mediocrities to the fate of all mechanical imitations. Truly artistic decoration in its whole scheme and in every detail is ever as spontaneous and free as the beauty and grace and sweetness of the "all a-blowin', all a-growin'" flowers of the Thames side meadows of a morning in May.

CAMEOS.[a]

By Cyril Davenport, F. S. A.

The word "cameo" does not in any way help toward a proper understanding of the term. The real derivation of the word is unknown. As we now understand them, cameos may be defined as small bas-reliefs cut upon some substance precious because of its rarity, beauty, or hardness.

The earliest examples of the art are perhaps to be found in the scarabs of ancient Egypt, combining both the cameo and intaglio, as their bases are engraved with designs. Early instances also exist in the form of small sculptures on the back of seal stones, of Greek and Etruscan origin, as also rarely in Mycenean work. Glass cameos were probably made at Rome long before the Christian era, and of still earlier date are found small rosettes and medallions of clay impressed with designs in relief and gilded.

The ancient Egyptian scarabæi are usually made in some soft stone, steatite, syenite, or serpentine, all of which can be cut by flint or obsidian flakes, or even by hard metal chisels. But harder stones were sometimes successfully cut, examples being found in amethyst, carnelian, obsidian, and jasper. The majority appear to have been made in molded glass or porcelain, usually with a green or blue glaze.

About the third century B. C. the peculiar adaptability of the banded onyx for cameo work was first generally realized, and it rapidly became the favorite material in which the most skilled artists worked; and cameos in time became valued articles of personal adornment, increasing in favor in proportion as the use of seal rings declined.

Onyx, which is a silicious chalcedony, is usually formed in irregular hollows in trap rock, and is deposited gradually in successive layers from the outer contours toward the center, alternately crystalline and amorphous. The crystalline layers are white in reflected

[a] Abstract of an address delivered before the Society of Arts January 15, 1901. Reprinted, by permission, from Journal of the Society of Arts, January 25, 1901.

light, the amorphous are translucent, grayish, and curiously permeable by liquids. In consequence of their permeability certain colors are sometimes naturally acquired by the amorphous layers of chalcedony. In cases where the water of infiltration is loaded with iron a yellowish red will probably be found, producing what is called a sardonyx, from a Persian word "zard," meaning yellow. Other metals will impart other tints.

Pliny (first century), in his Natural History, among other notes concerning jewels, says that (Book XXXVII) in his hands are books "wherein it is deciphered how to sophisticate transparent gems," a statement which likely enough refers to artificial coloring of chalcedony. But at the same time it may also only mean the paste imitations which were plentifully made both before and during the time the Natural History was written.

It is, I think, probably due to the discovery of the remarkable adaptability of the onyx stone for cameo work that the art has developed so as to become one of a considerable range and considerable importance both from the antiquarian and the artistic point of view.

Without this discovery we should not have possessed the Strozzi Augustus of the British Museum, or the Portland vase, or any of the works like them, bearing designs cut in one colored layer on a background of another, but we might have had the vase of St. Martin cut simply in an agate without any reference to the trend of its color layers, and the phalerae in chalcedony or amethyst, or any other stone of one color. But without the onyx cameos it is likely enough that all the rest would never have been considered more than small and delicate pieces of sculpture, not belonging to a school o their own, so that for the existence of cameos as a distinct branch of art we are probably indebted particularly to that unknown lapidary who first hit upon the idea of cutting the banded onyx parallel to its color layers instead of across them.

At Oberstein, in Oldenburg, there is a large onyx industry, originally fixed there because the stone was found plentifully in the neighborhood, but this supply having now become comparatively small, onyxes are sent there in quantities from India, Brazil, or Egypt to be sliced up ready for cutting, shaped, and artificially stained with colors as may be desirable.

The staining of onyx is well understood and is now reduced almost to a certainty, so that it is said that any ancient and presumably natural tint can be artificially produced with great accuracy:

Reds by means of pernitrate of iron.

Black by oil, honey, or sugar.

Blues by iron with ferrocyanide of potassium (prussian blue).

Greens by nitrate of nickel.

AUGUSTUS (SARDONYX CAMEO).

From British Museum Catalogue.

SCARABOIDS AND SELECT GREEK GEMS.

From British Museum Catalogue.

Heat alone will often darken and improve the color of an onyx.

Sulphuric acid will often improve the color of an onyx when metallic oxides already exist within it.

Nitric acid will often pale an onyx.

The white or crystalline layers are seldom meddled with. They can only be slightly reddened superficially by painting with a solution of iron or a little thickened by heat or strong acid.

Early carvings and engravings on hard stone were probably at first cut with a sharp diamond splinter alone; in time the diamond point was only used to sketch out the design on the polished surface of the stone, the actual cutting being afterwards done more easily and expeditiously by means of a hand drill, or some more powerful tool analogous to the modern jeweler's lathe. The harder stones require the help of oil and diamond dust to cut them, the soft iron points which are used becoming thickly coated with microscopic pieces of diamond and when rapidly revolved forming a very powerful cutting surface.

Emery is mentioned by both Theophrastus and Pliny as being the best material for rubbing down stones for engraving, the softer of which were probably sometimes engraved with flint points. Emery will polish a diamond; it is crystallized alumina and a variety of corundum.

For polishing ordinary stones rotten stone (powdered alumina) or tripoli powder (powdered silica) are most generally used. For polishing, of course, the material used must be softer than the substance to be polished, and the points used for carrying the polishing powders are also soft, copper, ivory, or wood.

My examples are arranged in three divisions: Antique subject or portrait cameos on small or flat stones; antique vases and cups on nodules of onyx or cut as cameos on blue or white glass; and the later or Renaissance cameos.

The Greeks were the most successful workers in cameo that have existed, the few remaining specimens of their work done during the early Ptolemaic period (third and fourth centuries B. C.) are unsurpassed, and the finest pieces made at Rome from the first century B. C. to the third century A. D. were actually the work of Greek artists. The universal acknowledgment of the surpassing excellence of the Greek workmen is marked in an interesting way by the fact that the extremely skillful Renaissance cameo cutters nearly all signed their names, if at all, in Greek characters.

Augustus Octavianus Cæsar, second Emperor of Rome, who reigned during the latter part of the first century, B. C., and the first few years of the Christian era, was evidently not only a splendid model for the cameo cutter, but also a man of much learning and culture

and a great patron of the arts. He is said to have been the original of Æneas as depicted by Virgil.

During the Roman Empire until the time of Constantine great luxury prevailed, and no doubt the lavish expenditure which was indulged in by the opulent and luxurious collectors of their time tempted the most skilled of the Greek cameo cutters to migrate to Rome and follow their avocations there more profitably to themselves than they could anywhere else.

Toward the end of the third century the Greek influence began to die out of Roman art in cut gems, and consequently there is a marked decline in the hitherto high standard reached in their production, and in the fourth century, when Constantine the Great moved his court to Byzantium, " Nova Roma " as it was sometimes called, a new style, Christian in feeling, began, and the classical designs hitherto prevalent were changed as to their attributes or superseded by others of new character. Hercules becomes David, Perseus and the Gorgon do duty for David and Goliath, Venus and Leda both become the Virgin Mary, and the heads of Medusa have the snakes cut away and are changed into the Holy face of St. Veronica. Byzantine art in cameos is not remarkably good; it is chiefly noticeable for the skillful manner in which advantage is taken of the natural markings of the bloodstone.

Some ancient portrait and subject cameos are of world-wide celebrity, either because of the exquisite beauty of the art displayed upon them, or for the size and beauty of the stones in which they are cut. The largest of these are both illustrative of scenes in the life of the Emperor Tiberius, who succeeded Augustus; one is at Paris (13 by 11 inches) and the other at Vienna (9 by 7½ inches). M. Ernest Babelon thinks these may both have been cut by the celebrated engraver of intaglios, Dioscorides. Then there is the beautiful double profile cameo at St. Petersburg, known as the "Gonzaga Cameo," representing, perhaps, Ptolemy II, Philadelphus, King of Egypt, and his wife, and another of the same king with his second wife, at Vienna. Adolf Furtwaengler considers these may be portraits of Alexander the Great and his mother Olympias. They were both most likely made during the early Ptolemaic period.

The large double portrait cameo, formerly in the Marlborough collection and now in the British Museum, is also one of the great cameos of the world; it measures 8¾ by 6 inches, and represents an emperor and empress facing each other, in profile, with the attributes of Jupiter Ammon and Isis.

The most beautiful single head in a cameo is probably the portrait of the Emperor Augustus, now in the British Museum, and formerly in the Strozzi collection at Florence (pl. I). It measures 5 by 3¼ inches, and is cut upon a most beautiful sardonyx. Another mag-

nificent single head, a portrait of the Emperor Claudius, measuring 7½ by 5¾ inches, but badly broken, is in the royal collection at Windsor.

Among the Renaissance cameos, as far as I know, there is only one of great celebrity, that is the small marriage group of Eros and Psyche, falsely signed "*ΤΡΥΦΩΝ ΕΠΟΙΕΙ*," which was formerly in the Marlborough collection and has now gone to America.

Besides the usual form of portrait or subject cameos so well known to us, samples of which you have just seen, there is another class which is important and perhaps not so well known or appreciated as it ought to be. These are the vases, dishes, and cups which are cut as cameos and made out of nodules of onyx or of blown and cut glass. There are now but few ancient examples of this development of the art of the cameo cutter left; most of them have succumbed to the destroying influence of time. It is said that when the Roman General Pompey brought back from Egypt the treasure he had captured from Mithridates, King of Pontus (first century B. C.), there were some 2,000 cups of carved hard stone among it. One of these is said to exist in the "Cup of St. Denys," now at Paris, but it appears to me to have the characteristics of later work. The "Tazza Farnese," now at Naples, and formerly in the collection of Lorenzo de Medici, is a flat agate dish (diameter about 8 inches), magnificently cut as a cameo, with figures probably of Egyptian divinities. It is considered to have been made during the early Ptolemaic period, probably at Alexandria. The "Vase of St. Martin," now at St. Maurice d'Agaune, in the Rhone Valley, is an onyx cup, dark, still with its Byzantine setting; it is probably early Byzantine work, or possibly late Roman mounted by Byzantine artists. The small but exquisite chalcedony vase (8½ inches high) recently bequeathed to the British Museum by Baron Ferdinand de Rothschild, belongs to this class. The lip, lid, and foot are of enamelled gold, added probably in the sixteenth century.

Besides these, which are all of the first importance, are the remarkable works of the same kind, but executed in glass; the Portland vase, in the British Museum, the Vase des Vendanges at Naples, and the Auldjo vase in the British Museum. The Vase des Vendanges alone is perfect. These are all antique, and as exquisitely worked as if they were made of the most valuable stones. The Portland vase is the finest of them. There are numerous fragments still existing of vases of this kind which have been broken.

These glass vases are indeed glorified "pastes," of which numbers were made during the time of the Roman Empire and just before it. As a rule pastes imitated intaglios and were cast from clay molds, and there are examples of paste cameos probably made as early as the second century, B. C. These are rarely satisfactory because of the difficulty of persuading the glass for the part in relief to keep to its

own ground. In the case of the vases, however, the procedure has been different, the reliefs have not been cast, as Wedgewood reliefs are for instance, and then stuck on, neither have they been cast in one piece with the darker glass of the ground, but the vase has been made in the dark glass first, then dipped in white glass so as to be entirely coated with it. The vase has then been treated exactly as if it was a stone and the cameo cutter has cut the glass in the same manner as he would an onyx. None of these cut glass vases have now a high polish, but it is possible that they originally had, as some of the glass placques of similar workmanship and about the same date are polished.

After the Byzantine period until the Renaissance, i. e., until the fifteenth century, there is a lack of consecutive art in the direction of cameo cutting. The Byzantine cameos are not remarkable for beauty in design or execution. They are largely cut in bloodstone, the peculiar coloration of which was peculiarly fitted for representations of the crucifixion.

Christian designs prevailed as a rule until the end of the fifteenth century, when the Renaissance began, and classical designs in their turn replaced those taken from biblical sources.

The earliest great patron of cut gems of the Renaissance period was Cardinal Bembo, afterwards Pope Paul II, who made a fine collection. He is said to have so loaded his fingers with rings set with gems that they chilled him to death. His collection was largely acquired by Lorenzo dei Medici, called the "Magnificent," who ruled in Florence during the latter half of the fifteenth century. The revival of the arts which took place in the fifteenth century is generally considered to have been largely due to the patronage of this great Italian. He had many of his gems engraved with his name. The Medici collection is now dispersed chiefly between the Museums of Naples, Florence, and Paris.

Renaissance cameos are remarkable for the technical skill displayed upon them and the beauty of their settings. Benvenuti Cellini is credited with two settings for cameos now at Paris. Although the general level is high, there are no really great cameos of the Renaissance period. It was indeed a revival of the art only, and does not add anything new to the existing styles. There were innumerable imitations made of antiques, many of them most skillfully. Names of celebrated engravers were frequently added both to inferior antiques and to new gems, but cameos have fortunately not suffered nearly so much from fraudulent imitations as their cousins, the intaglios.

From the sixteenth century to the present time shells have been largely used for small cameos. It is, technically, a different art from

GRÆCO-ROMAN GEMS.

From British Museum Catalogue.

GREEK AND ROMAN PORTRAITS.

From British Museum Catalogue.

the cutting in hard stone, and is executed more after the fashion of a wood carving, as the shell is comparatively soft.

Queen Elizabeth caused her portrait to be cut in cameo several times; some of these have no doubt been executed by Julien de Fontenay, called "Coldoré."

In later times Italian artists have most notably followed the profession of cameo cutting. Flavio Sirletti, in the eighteenth century, is said to have nearly reached the Greek perfection of technique. Giovanni Pichler and Sirletti, too, cut some cameos with the diamond point alone as an experiment. Jean Laurent Natter, of Nuremberg, flourished in the same century; he was particularly successful in his imitations of the antique, and in all probability numbers of so-called "Græco-Roman gems" are really his work. He made a catalogue of the Bessborough gems, afterwards part of the Marlborough collection, and he also wrote a valuable treatise on the ancient and modern systems of engraving and cutting gems in hard stones.

Alessandro Cesati, called "Il Greco," was noted for his fine draftsmanship. Madame de Pompadour learned the art of gem cutting from the French artist, Jacques Guay, who made cameo portraits of her, Louis XVI, Marie Antoinette, and others. Guay could hardly write, and it is supposed that the signatures in his cameos were cut by someone else.

In the nineteenth century the decline in the popularity of cameos has been marked; indeed, although there are several names of known artists sometimes who have them, that of Benedetto Pistrucci alone has reached a point of eminence. Pistrucci came here from Rome early in the century, and eventually became chief engraver to the royal mint. He designed the beautiful group of St. George and the Dragon, which is still used on the reverse of some of our coins now in circulation. He wrote an interesting autobiography, in which he tells the story of a head of Flora, cut by himself, which was sold to Mr. Richard Payne-Knight as an antique. Pistrucci showed his mark on the gem, but Mr. Payne-Knight disbelieved the story.

THE ECONOMIC CONQUEST OF AFRICA BY THE RAILROADS.[a]

By A. Fock.

The division of Africa among the European powers through the definition of spheres of influence is to-day an accomplished fact. Nevertheless, the lines so arbitrarily traced on the map will never constitute a barrier against any economic advances. There will be always an industrial and commercial warfare, which will allot to each European nation its field of action and its lines of advance into the interior of the Dark Continent.

For, until economic supremacy is assured in a colony, political domination is little more than a name.[b] The attainment of the former should be the sole aim of the latter; without it a government will, so to speak, snatch the chestnuts out of the fire for the benefit of its competitors.

The first step after the military occupation is the organization of the civil and administrative branches; then the duty of the power is but begun. But, above all other things, it must immediately open up some means of communication at once sure, rapid, and economical.

The African problem at this time, therefore, resolves itself into a question of the construction of a system of railroads. Since the continent is too compact to be opened through waterways, the only practical means of reaching the interior is by recourse to the locomotive.

Everything considered, the railroad is the peaceable but none the less decisive force which, ably directed, will determine the industrial and commercial supremacy in Africa. Some European countries, more inspired that their rivals, realized this fact long ago. Taking the lead, they have unrolled ribbons of steel toward distant inland

[a] Translated and abridged, by permission, from the Revue Generale des Sciences Pures et Appliquees, Paris, Mar. 15, 1904.

[b] "Where economic supremacy subsists political rivalry is not dangerous; where political supremacy subsists economic rivalry can undermine it; where neither subsist economic invasion prevents political invasion by a rival." Alexander Ular: England, Russia, and Thibet. (The Contemporary Review, December, 1902.)

posts, which, much to their profit, are to-day centers of economic progress. These advances have enabled the more alert nations to acquire without opposition very favorable positions and to attain, for the moment at least, an unquestionable advantage.

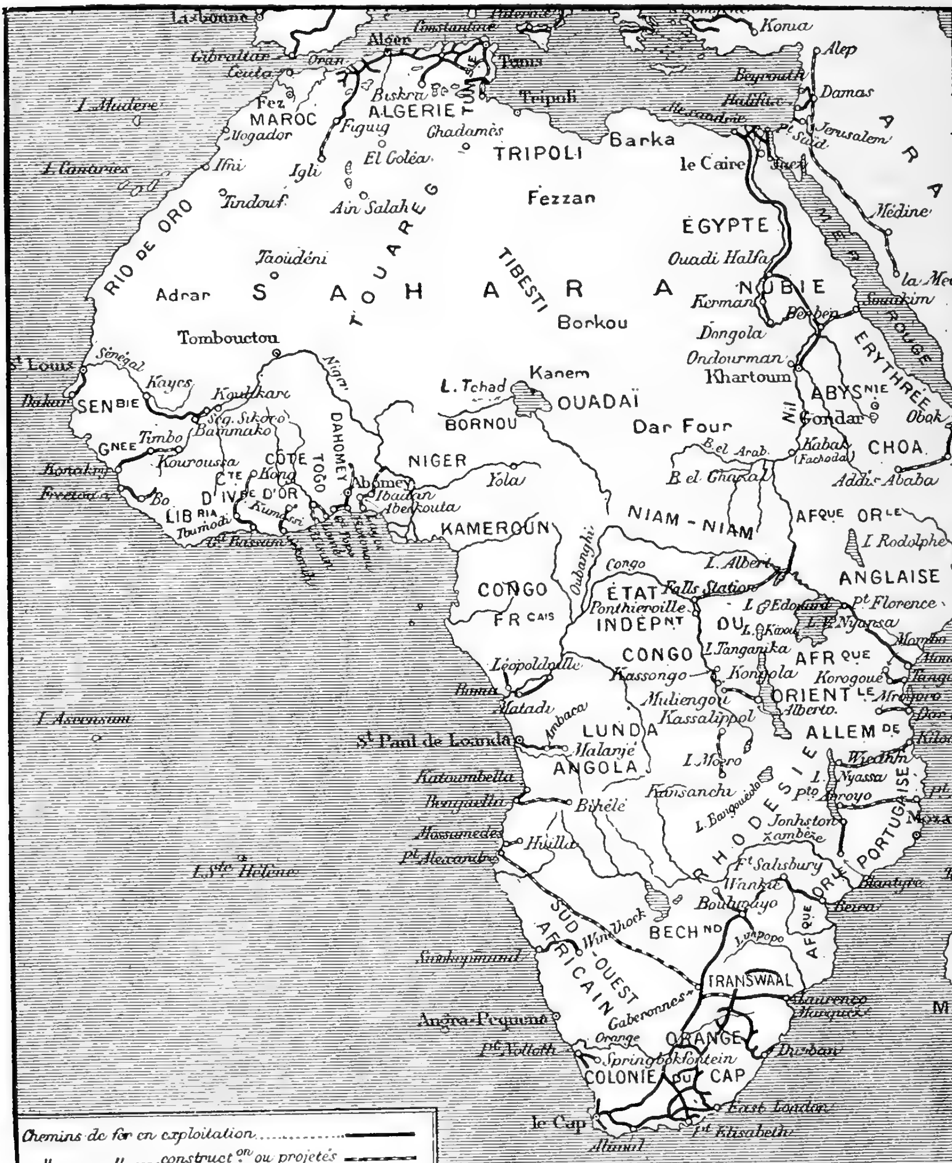


FIG. 1.—Map of Africa, showing railroads in operation and under construction.

An examination of the accompanying map (fig. 1) will show that properly speaking there are but three railroad systems in Africa—the Tunis-Algerian, the Egyptian, and the South African. The first named is complete in itself. The other two will serve as bases on the north and south for the great artery from Cairo to the Cape. As for

transverse routes, the English, German, and Portuguese roads on the coast of the Indian Ocean, together with the Belgian, English, and Portuguese enterprises on the South Atlantic, constitute the beginnings, already well developed, of two or possibly three lines of direct communication between the east and west coasts lying below the equator.

Finally, there are those French, English, and German railroads of Western Africa, like those on the Red Sea, entirely independent, and built for the purpose of connecting with navigable rivers or opening a means of exportation for the goods of some inland country. Among the roads in operation and already more or less connected which are now being organized in the principal colonies are three or four proposed transcontinental lines—one from the Mediterranean to the Cape, and the others from the Atlantic to the Indian Ocean. The work on these is being pushed forward simultaneously from both ends. Besides the great systems already spoken of, there are a number of isolated roads running from the coast short distances into the interior. Entirely autonomous, each with its peculiar object, these little roads are built as occasion demands, and are in several territories already at work. Such, at the beginning of the twentieth century, is the situation in Africa with regard to railroads.[a]

The first railroads established in Algeria more than thirty-five years ago—the Algiers-Oran and the Philleville-Oran routes—were concessions to the Compagnie Paris-Lyon-Mediterranee. Companies exclusively Algerian were formed in 1875, and for the next sixteen or seventeen years these companies constructed continually. But since

[a] Below is a table which recapitulates for the year 1903 the length, in miles, of the railroads now in operation in the different regions of Africa:

	Miles.
French colonies:	
Algeria	1,822
Tunis	586
West Africa	524
Djibouti	184
Reunion Isle	90
	3,206
Egypt:	
State roads	1,395
Private companies	712
Military line in Sudan	776
	2,883
English colonies:	
Cape Colony	2,122
Natal	596
Transvaal and Orange Free State	1,322
Rhodesia	1,143
East Africa	582

	Miles.
English colonies—Continued.	
West Africa	186
Mauritius	88
	6,039
German colonies:	
East Africa	31
Southwest Africa	121
	152
Portuguese colonies:	
Dongola	338
Mozambique	249
	587
Italian colony:	
Eritrea	247
Congo Free State	247
Grand total	13,121

that time the Parliament has shown itself indisposed to grant further appropriations and everything is at a standstill. During the last decade three roads of purely local interest have been developed at the expense of the national system.

The great central Algerian railroad runs parallel with the seacoast from Tlemcen to Sidi-el-Hani, a distance of about 750 miles. At Oran it divides into two short branches. Tunis, at the other extremity, is connected by branches with the principal ports of three provinces. There are three inland roads, no one of which, however, can be extended independently into the interior. Railroad construction in Algèria is practically at a standstill.

In fact France seems to be committed to what the English call a "masterly inactivity." She has neglected to take advantage of the

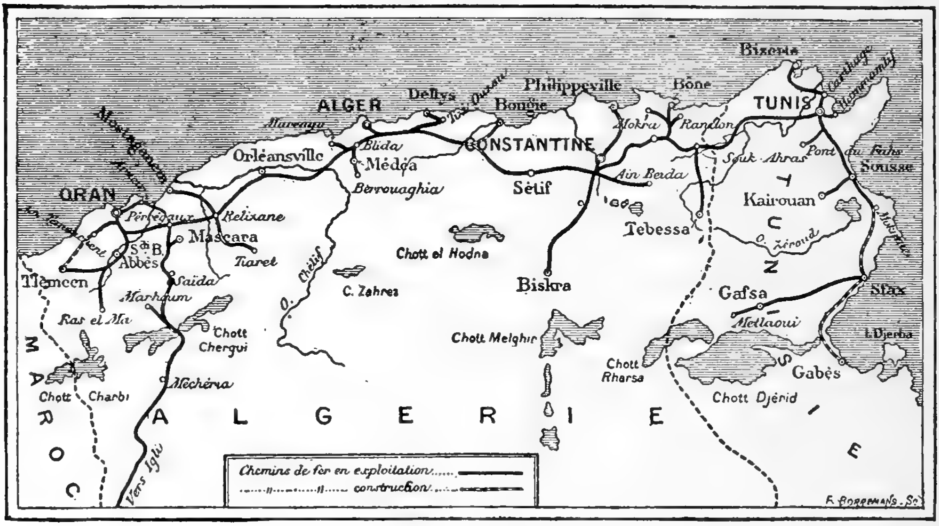


FIG. 2.—Systems of Algiers and Tunis.

incomparable base of operations for an advance into the interior offered by her Mediterranean possessions, and in the possessions themselves has contented herself with an insignificant system, the elaboration of which is too often governed by political considerations rather than those of a purely economical nature.

When the contracts are rewritten, the companies merged, the tariff revised, and the headquarters moved from Paris to Algiers, the work of construction in Algeria will receive a new impulse. However it may come about, the new era will put an end to the standstill policy and inaugurate a period of progress. The independence in financial affairs which the colony now enjoys gives the means of appropriating necessary money for railroads. To the great profit and economic glory of French North Africa rational extensions will be undertaken as the occasion arises.

In sharp contrast with Algeria the protectorate of Tunis is working energetically to provide the regency with a number of railroads. One company, the Bône-Guelma, has built the whole system with the single exception of the line from Sfax to Gafsa, which was established solely for the purpose of hauling the crude phosphates from Metlaoui. The "old" system, as it is called, is the extension to Tunis of the Algerian main line; the "new" system is made up of coastwise lines, with three branches into the interior.

The next step will be the extension of these branches far enough inland to make them commercial lines. Such was the intent of the law of April 30, 1903, which authorized the Tunisian Government to make contracts to the extent of $8,000,000. From Pont du Fahs, a line will be run as far as Kalaat-es-Senar and then be turned toward Sbiba. Both of these places are in the midst of great phosphate beds, which the franchise holders are not only allowed but expected to work. Another road will be run from the iron district of Nezfas to Bizerta, and Sfax will be connected with the Sousse system, bringing into the system the now isolated Sfax-Gafsa line.

One can not but remark the rational and just policy which has prevailed in this protectorate; everything has been worked out with an eye to the economic development of the country. But it is only fair to say that Tunis has enjoyed from the beginning the freedom of action which Algiers achieved only last year. Political interference, so common in Algiers, and petty local rivalries, like those of Oran and Constantine and Bône, are scarcely to be found in the land of the bey.

The only one of these town struggles worth mentioning is that between Bizerta and Tunis. Bizerta, a port of some military importance, is desirous of becoming a great commercial center as well. Its interests therefore clash with Bône on one hand and with Tunis on the other; but this rivalry has had an effect beneficial rather than otherwise on the railroad development.

The European power to whom the honor of having done the greatest work toward the introduction of the railroad into Africa is, unquestionably, England. Before long British locomotives will cross the continent from Cairo to the Cape. In the northeast they already run to Khartoum, a distance of nearly 1,400 miles from Alexandria. Egyptian trains which formerly had their terminal at Assiut (225 miles south of Cairo), now go 78 miles farther on tracks laid by the English in 1881 to reach Keneh. From this point to Assuan, near the first cataract of the Nile, the road is in the hands of a private corporation. Still farther on is the military line into Sudan, pieced onto the Egyptian system by the little fragment built in 1874–75 between the first and second cataracts.

This military line is interesting for many reasons. It has two branches, one through the Nubian desert and the other extending into the province of Dongola. Although laid with extreme repidity, the average expenditure per mile did not exceed $15,200. Of course there were practically no great feats of engineering involved. At one place there is a straight level stretch of 45 miles. The declivities average less than 0.008 m. and, excepting the Atbara bridge, some 1,200 feet long, there was no particular difficulty of construction.

But the hasty manner in which the road was built entails constant repair and necessitates a series of supplementary works, which will increase somewhat the initial cost per mile.

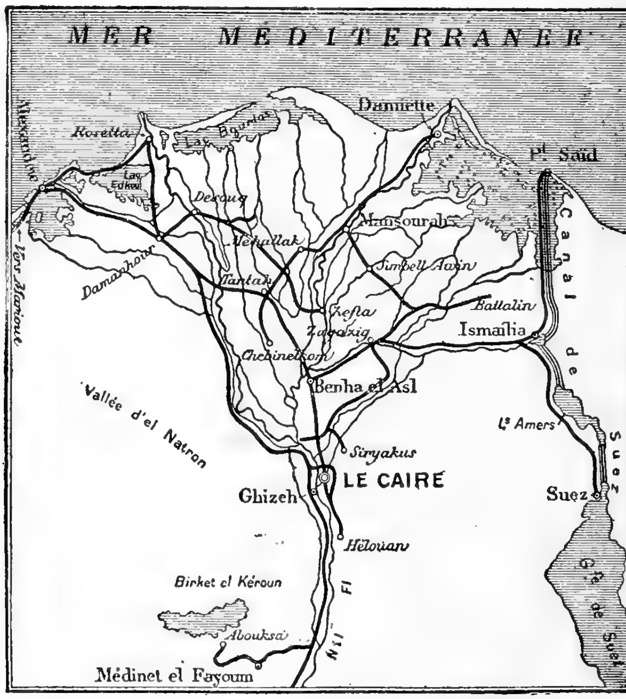


FIG 3.—Egyptian system.

The roads south of Wady Halfa already furnish very useful data concerning railway operations in a desert country. On them it is possible to make observation on the rapid wearing away of the rails by the sand and the destruction of the cross-ties by neuptera. Water trains are found necessary, since in the whole stretch of 237 miles between Wady Halfa and Abou-Hamed water could be reached but twice—then by boring, in one case 858 feet and in the other 975 feet.

At the point last named, although the summer heat is excessive, there is a roundhouse for locomotives, with a shop for small repairs. The main shops at Wady Halfa and Shendi have the very difficult

task of keeping in running order seven different types of locomotives, garnered by the military authorities in their haste to open the road.

The weekly schedule at present includes two express trains, admirably equipped with parlor, buffet, and sleeping cars. Besides these a mixed freight and passenger train starts daily from each end of the line. The shipments to the south consist of military stores and construction materials, while the northern freights are made up of rubber, ivory, ostrich plumes, and grain. As the list indicates, the tonnage is still of very modest dimensions, yet it is sufficient to pay a good share of the expenses of operation.

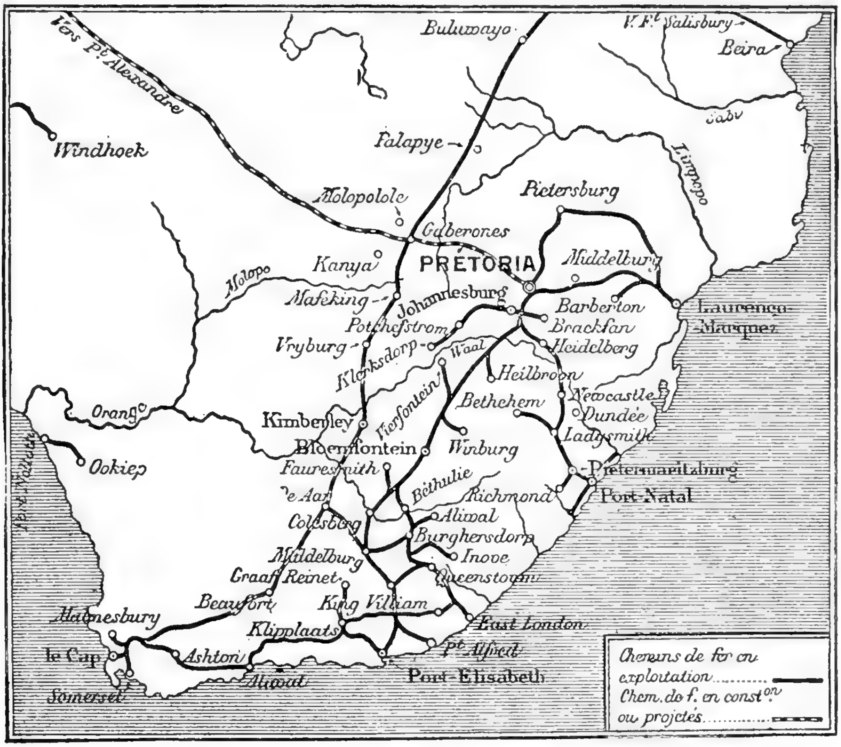


Fig. 4.—South African system.

The extension to Lake Albert of the northern section of the proposed transcontinental road between Cairo and the Cape is postponed for the present. Instead the English have decided to undertake the construction of a road from the Nile to the Red Sea. The attempt to join Berber and Suakin was abandoned in 1881, after an immense amount of money had been spent on some 20 miles of road; but the project has been revived, and to-day work is being done on both ends of a road between Suakin and Khartoum by way of Kassala. From Kassala it is planned to run a great southern line through Abyssinia to Lake Rudolph, and thus connect the Egyptian system with that of eastern Africa.

The counterpart of the continuous semicircle of railroads from the Mediterranean to the Indian Ocean, which is still in a state of projection above the equator, exists as a fact in the southern part of the continent, for, on October 6, 1902, at a point 600 miles from the eastern coast and 1,365 miles from the Cape, was made the junction between the lines running westward from Beira by way of Salisbury and those running northward from Cape Town by Bulawayo.

During the last twelve years the South African railroad system has grown with astonishing rapidity. When the chartered company was founded, in 1889, the road from the Cape went only to Kimberley and that from Beira was not even thought of. To-day, after a period of feverish activity to which not even the Anglo-Boer war could put an end, the number of miles of railroad in the vicinity of the Cape is nothing short of marvelous.[a]

In Rhodesia especially, under the resistless energy of Cecil Rhodes, the railway has taken a great leap forward. The Cape Colony road comes to an end at Vryburg; beyond that point the construction of the southern section of the Cairo transcontinental line is assumed by the Chartered Company, which steadily continues its progress toward the north. Bulawayo was passed some time since; Wankies, with its coal fields, has just been reached. To the 200 miles just completed will soon be added the 72 which lie between Wankies and the Zambesi. A bridge, nearly 700 feet long, across the river just below the celebrated Victoria Falls, will enable the locomotive to reach the copper mines recently discovered in Rhodesia. Ascending to an altitude of 5,000 feet, the road will proceed toward Lake Cheroma. On the salubrious plateau in which the lake is situated the company proposes to establish one of its principal transcontinental stations, which, it is expected, will prove very important from a sanitary viewpoint. The proposed line then descends to the level of Lake Tanganyika and terminates at Abercorn, on the southern extremity of the lake.

It will then remain only to cross the Belgian and German territory which lies between Tanganyika and Victoria Nyanza, the final sec-

Length of So th African railways.

System.	Lines in operation in 1902.	Lines under construction-	Total.
Cape government roads	2,394	1,025	3,419
Rhodesia roads	1,632	559	2,191
Beira line (Portuguese)	182		182
Natal government roads	611	297	908
Central South Africa roads	1,337	627	1,964
Delagoa Bay (Portuguese)	58		58
Total	6,214	2,508	8,722

tion of 520 miles between Ujiji and Mengo. All this is but vague planning so far, because there has been as yet no understanding with Kongo or with Germany.

Moreover, all the railroad activity in Rhodesia just now is in the immediate vicinity of Boulouwayo. This capital, which aspires to become the Chicago of South Africa, is so rapidly becoming a center for coal roads that it looks as if its ideal will be attained in the near future. The coal fields at Wankies, near by, are of a wonderful richness. They cover an area of more than 600 square miles, with deposits 6 feet thick of coal almost equal to the better English grades. The opening of these fields will greatly aid the economic development of the country and largely increase the use of railroads. It is noteworthy that, in spite of the Boer war, the commerce of Rhodesia has increased 400 per cent during the past six years.

The three principal African systems present the greatest diversity in their equipment, but in no respect is the variety of types more marked than in the matter of the gauge of the track. The width varies from 0.60 meter at Swakopmund, in the German southwest, to 1.435 meters in the Algeria-Tunis system, but everything indicates that the narrow-gauge, from 1 to 1.067 meters, which is now most common, will be used almost exclusively in the future.

After having overcome every obstacle and put into successful operation the railroad of lower Kongo, the Free State is now planning to open means of communication with its eastern frontiers. It proposes to establish, within six or seven years, a line running across the continent from west to east, which will combine transportation by rail and steamboat.

When this line is completed, passengers and freight will be carried over the following route: By sea to Matadi, in the navigable estuary of the Kongo; by rail from Matadi to Leopoldville (Stanley pool), a distance of 242 miles; by steamer to Stanley Falls. At Stanley Falls the road branches; the northeast arm comprises a railroad to Lake Albert, boat across the lake, railroad between Lake Albert and Victoria Nyanza, boat across Nyanza, and the Uganda Railroad to Mombassa, on the Indian Ocean. The east and southeast branch will consist of a railroad, to avoid the rapids, and a steamer for a 300-mile voyage up the river to Kassongo, where the road again branches. One of its arms will reach Albertville, on the west shore of Lake Tanganyika, whence the German lines on the opposite side are expected to put it into communication with the coast. The other section will continue by boat up the Kongo as far as it is navigable, avoiding the rapids by railroad. The position thus obtained on the southern borders of the Free State will ultimately, it is expected, be put into communication with the North Rhodesia system.

East of Stanleyville this Belgian transcontinental route, with its alternate locomotives and steamboats, will spread out, fanlike, in three directions. The line in the center, with the assistance of the German roads, will go direct to the east coast; the two extreme routes will open out on the English system, so as to establish uninterrupted traffic with Cairo on the north and the Cape on the south. The accomplishment of this project, as a whole, would bring about a complete transformation of the equatorial regions, which would in turn affect every part of the African continent.

Before the opening of the lower Kongo line the transportation of a ton of merchandise from Stanley Pool to Matadi took twenty-one days and cost $200. Now the journey is made in twenty-one hours, with a proportionate reduction in cost. The effect of this on the production of rubber is significant. In 1887 there were exported 30 tons, with an aggregate value of $21,355; in 1900 the amount shipped exceeded 5,300 tons, and was valued at $7,974,801.

Adequate transportation from Stanley Pool to Stanley Falls is assured by the presence of a fleet of over 100 steamers. The largest of them belong to the Kongo Free State, which owns nearly 30; the Belgians operate a score, and the French 40 or more.

The work on the line between Stanley Falls and Mahagi is now completed. Although the way had to be cut through the virgin forest the task was not an extraordinarily hard one. Except for the swamps there were no real obstacles. The passage over the Blue Mountains between the valleys of the Kongo and the Nile entailed a great expense, but failed to raise any difficult problems in engineering. Mahagi, the northernmost of the Belgian stations on the Nile, looks down upon Lake Albert. Having an excellent climate, good air, and atmospheric conditions favorable to Europeans, it is eminently suitable for the terminal depot of a great railroad.

Meanwhile the English have got the start on the Belgians in the region of the great equatorial lakes. Early in 1902 the locomotive made its appearance on the border of Victoria-Nyanza; the last rails of the Uganda Railroad had just been laid. This enterprise may well be considered the greatest triumph of African railroad construction. It offers a unique example of a single stretch of nearly 600 miles of rail run through an absolutely uncivilized country, where obstacles of every kind accumulated in a manner truly extraordinary.[a]

For the first 180 miles the engineers had to contend with the terrible climate of the low coast regions, as deadly to man as was the tsetse fly to the beasts of burden. The mortality among the latter, imported

[a] Correspondence concerning the Uganda Railway. Report to Parliament, July, 1901.

from the Cape, Cyprus, and India was frightful. Among the laborers the average rate of death by fever was over 3 per cent. Native workmen were entirely lacking, and it was necessary to bring more than 20,000 Indian coolies, whose transportation and keep entailed a heavy expense. Since the resources of the country were practically nothing, such an army of laborers could not be maintained without having all the provisions shipped from Bombay and Colombo. It was especially difficult to secure fresh water during the building of the first 250 miles. Thus handicapped the work of construction advanced very slowly.

On reaching the mountains the situation changed completely. The insanitary conditions disappeared; an abundant supply of fresh water was found. But as the troubles about workmen were diminished, in their place arose great technical problems. The complete ignorance of the engineers as to the behavior of the water in that region during the rainy season made it very difficult to plan bridges and viaducts. Moreover the scarcity of construction materials complicated continually the work of the builders. For example, it was impossible to find any suitable brick clay.

The work was begun in 1896 and finished six years later. The line, which extends 587 miles over a variety of levels, begins at Kilendini, on the Island of Monbasa, and terminates at Port Florence, on Victoria Nyanza. The tracks consist of 55-pound rails laid on metal ties, except in spots where the sun is so scorching that it was necessary to use wood ties treated with creosote.[a]

The stations are built partly of masonry and partly of sheet iron, corrugated and galvanized. In 1902 the company owned 92 locomotives, of which 22 were switch engines; there are 154 passenger and 1,123 freight cars. A daily train is run, besides an express and four freights each week. Ordinarily the rate of speed is about 15 miles an hour, the whole run taking nearly two days. During the year 1901–2 the shipments did not exceed 11,000 tons in and 1,250 tons out; the gross receipts were only $350,000. Since the expense of construction was over $26,000,000, the question naturally arises as to how far the results thus far obtained have justified this expenditure.

Without dwelling on the fact that the line has not yet completed its second year, it is necessary to call attention to the great change that the establishment of the railroad has wrought in English East Africa. Indian merchants have established stock farms along the line and opened markets at the principal stations. Their stores are all well stocked, particularly that at Nairoli, where manufactured articles of every description and even luxuries may be obtained at a very slight advance over regular prices.

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[a] These wood ties are not attacked by the white ants.

Nairoli, chosen on account of its healthfulness as the center of operations for the road, is a bustling little city of 5,000 inhabitants in a spot where solitude once reigned supreme.

In the Kikuyu region agriculture has made decided progress. In the extensive gardens there are raised nearly every variety of the vegetables and fruits of Great Britain.

At Port Florence a wooden pier extends 130 feet into the lake, so that the steamers can land without difficulty.

The Uganda Protectorate owns two steamboats of 600 tons displacement; these draw less than 5 feet of water, but can carry 12 first-class and 100 deck passengers, besides a good cargo. Stopping at the principal points, it takes three days to make the trip from Port Florence to Entebbe, halfway round the lake.

Taking into consideration, therefore, the whole of this new state of affairs which has come into Uganda and the Upper Nile with the opening of the railroads, one can but see that it will not be long before England's financial sacrifice will be rewarded by the rapid economic advance of these rich provinces which have been enabled to enjoy quick and reasonable transportation. The aftermath will be a continued growth of shipments by rail and a corresponding growth in the receipts of the railroad.

Having looked at all the English and Belgian projects for a transcontinental road from east to west, there still remain to be considered two colonies on opposite coasts—German East Africa and the Portuguese colonies on the Atlantic.

The projects most favored in Berlin are intended primarily to join Tanganyika with the Indian Ocean. But the lack of enthusiasm shown by the Reichstag for African enterprises has not encouraged the administration to ask for the necessary funds. Only the most modest enterprises have been undertaken, although, according to governors von Liebert and Goetzan, the rapid development of railroads is a question of life and death for the eastern colony. The embryo system of German East Africa now consists of the first section of the Usambara railroad, the fifty miles getween Tanga and Korogwe. Begun in March, 1902, this portion has cost thus far 6,500,000 marks; it will be extended 40 miles to Mombo. Owners of coffee plantations in the colony expect to derive great benefits when this line finally put in working order. Just now the efforts of the colonists are directed toward obtaining permission from the Reichstag to construct immediately the 142-mile line between Dar-es-Salaam and Mrogoro.

On the Atlantic coast the Portuguese have for a long time operated the line from Loando to Ambaka, an important industrial center; this is to be extended eventually to Malanji, but there is no thought of crossing the continent in this enterprise.

An entirely different idea obtains in the minds of the promoters of the Angola-Benguela railroad which was conceded to an English company in 1902 by the Government at Lisbon. The proposed route starts at the Bay of Lobito, follows the boundaries of the two provinces, runs as far as Caconda and stops for the moment, after a run of 850 miles, on the eastern boundary of the Portuguese possessions. The work is to be completed within eight years; the company has reserved for itself, among other privileges, the right of working the forests of the State and that—a very valuable one—of working all the mines found within a zone of seventy-five miles on either side of the track.

Without waiting to see the outcome of this tremendous project, the characteristic enterprise of the British has inaugurated a second scheme to be developed simultaneously. Being the owner of the great copper and lead mines at Tsumel, the South West African Company decided to build a railroad to Port Alexandria in Middle Angola to put them in communication with the Atlantic. In making plans for this, they suddenly hit upon the scheme of running from the same terminal a transcontinental line eastward to the capital of Transvaal. This road will intersect the Capetown-Bulawayo line about Gaberon, making the junction at a point 630 miles from Port Alexandria and 458 miles Capetown. Since these two towns are about 1,260 miles apart on the shore line, and since Capetown is only 204 miles nearer Pretoria than is Port Alexandria, it seems but reasonable to presume that in the future the commerce of Western Europe with the old Boer republic and Rhodesia will go by way of Port Alexandria, which will in that case become a formidable rival to the capital of the Cape of Good Hope.

Having reviewed the three great systems and the various transverse lines, it now only remains to glance at the series of independent roads, the larger number of which are in the west coast colonies. In this field of action, more restricted but very interesting nevertheless, the first place belongs undoubtedly to France. For some years that country has displayed real energy and impartiality in an effort to hasten the introduction of the locomotive.

The Senegal road from Dakar to St. Louis for a long time was the one favored enterprise. Construction on the railway directed inland towards the Niger dragged desperately; it seemed as though every possible obstacle was thrown in the way of its achievement. Things are at last beginning to look brighter. Two hundred miles of the road is now in actual operation, the embankments have reached a point 100 miles beyond Kiba, and will go as far as Koulikoro in 1904. Within eighteen or twenty months the entire 350 miles between Kayes and the Niger will be put into use.

This event will exercise an incalculable influence on the agricultural and commercial development of the vast regions situated in the bend of the great river. To accentuate the value of this road, which will be of especial benefit to the culture of cotton, the governor-general of Western Africa is planning a line from Thies to Kayes. This would make an unbroken stretch of rails from the ocean to the Niger.

Farther east, the railroad starting from Cotonou will eventually reach the same stream at Carimana above the falls of Boussa. Thus the whole group of French colonies of the West Coast will be girdled by a semicircular artery of trade, 1,200 miles of which will consist of navigable river.

The Dahomey line was begun in 1900; at the end of two years 60 miles of it was in actual use. A few months ago a locomotive had been run a distance of 150 miles to the temporary terminal at Paouignan. From here it is expected to go, without much difficulty, to the Niger at Carimana, about 500 miles from the sea.

In Guinea the road from Konkary to the Niger has about 90 miles of tracks laid; no doubt two or three years will pass before it attains Timbo.

Ivory Coast, like the other French colonies, has cherished a railway scheme for a long time, but has been continually put off by the flurry over gold discoveries. A recent decision by the ministry, ordering to be constructed the first 45 miles of the proposed line, has finally brought satisfaction. As in Guinea and Dahomey, the road will be built under the direction of the engineer corps of the army, which in this instance will have complete supervision of both track and roadbed.

Any account of French railroad operations in the Dark Continent would be incomplete did it not mention the line, which has so aroused the jealousy of the British, thrown out toward the high plateaus of Abyssinia by the Somali coast. The firm and sensible position taken in the matter by the French Government in 1902 has not yet reaped its full reward. The climate at the base of operations on the Red Sea is so unfavorable, and the country to be traversed so mountainous, that the road will not reach Harar for nearly six years. Since February, 1903, plans have been made for its further extension to Addis-Abeda.

The English as yet have litle reason to felicitate themselves on the results of their railroad building in the Guinea Gulf colonies. In Gold Coast, the Government, after spending $47,000 a kilometer on 40 miles of track, was glad to turn the work over to a contractor, who agreed to finish the 140-mile section between Tarkoua and Kumassi for $21,000 a kilometer. One hundred miles of the railroad, from Sekondi to the gold beds of Ashanti, is now completed.

In Lagos the work was carried on a little more economically; there it cost only $30,000 to lay a kilometer of track. This line is now running between the coast and Ibadan; it is to be extended northward some 120 miles. On reaching the Niger it will be continued up the left bank of the river in the direction of Zoungerou, the new capital of Nigeria. This bit of railroading is undertaken at the suggestion of Sir Francis Lugard, with a view to opening up the vast stretches of land suitable for cotton raising.

The German Agricultural Company in Kamerun is busily occupied in covering the whole of its concessions with a web of industrial lines. But this purely local work is insignificant when placed alongside of that proposed by a Berlin syndicate organized in 1902, which expects to have completed by 1905 a line runing northeast 130 miles into the interior. The importance of this road will be realized when it is understood that it will probably form the first section of a great German trunk line, 340 miles long, which will have its terminus on the shore of Lake Chad. In return for the services which this line will render to the cocoa, tobacco, and cotton plantations it has been granted 50 hectares of land. Besides this the railroad expects as soon as its locomotives have worked into Borneo, to draw into its hands the entire commerce of central Soudan.

The German possessions in the southwest have not fallen behind; they also have there 120 miles of railroad between Tsoakhaubmund and Windhock. The whole distances is in working order, and the road is especially valuable in carrying Government supplies. In the olden days it used to cost $96 to haul a ton of merchandise on an ox cart from the coast to Windhock; it now costs but $11.20 on the railway.

Thanks to the services of this road and to the great granite jetty recently constructed in connection with it, Tsoakhaubmund is destined to become the shipping place of the copper taken from the mines at Otavi.

From this brief discussion of railroad activity in the Dark Continent several general conclusions are apparent.

England, through her various roads and her much talked of transcontinental from Cairo to the Cape is already assured the commercial supremacy of eastern north and south Africa: in fact of a good half of the Dark Continent. The Kongo Free State will derive in the near future the riches, agricultural and commercial, of her vast territories by the opening of a giant system, in which river and railroad will aid in forming a great transverse artery in the zone of the equator. In western Africa the preponderant part devolves unquestionably upon France.

THE PRESENT ASPECTS OF THE PANAMA CANAL.[a]

By William H. Burr.

Inasmuch as it is scarcely nine months since the present Isthmian Canal Commission was created, and as the first month and a half of that time was nearly wholly occupied in its first visit to the Isthmus for the purpose of inspecting the work about to be acquired by the United States, any view of the Panama Canal project at this early date must be a consideration of what has been transmitted from the New Panama Canal Company to the United States Government, rather than a review of plans adopted or of methods of construction for the great work undertaken. Indeed, it must be borne in mind that the title of the Panama Canal property was actually transferred to the United States Government only on May 4, 1904, so that the Commission has been in control of the canal property but seven months at this writing.

The full report of the former Isthmian Canal Commission of its work performed "with a view to determining the most practicable and feasible route for" a ship canal across the American Isthmus is a complete compendium, not only of all data existing at that time regarding the canal property, but also a comprehensive statement of the plans and estimates of that Commission regarding the type of canal recommended by it. The conditions under which the canal is to be built and the character of the ocean traffic to be accommodated have changed so radically within the period elapsed since the old Panama Canal Company went into bankruptcy that the work before the present Isthmian Canal Commission must necessarily be largely independent of anything hitherto contemplated, and its plans must be developed and completed for practically an entirely new project. This is a necessary procedure for a number of important reasons. Among others, during the past three years, even, material developments in the size and motive power of steamships have been made and those developments are in active progress at the present time. Steamships over 700 feet long have been built, and there are already serious state-

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[a] Reprinted, by permission, from The Engineering Magazine, New York, January, 1905.

ments from ocean transportation companies regarding the building of ships approaching 800 feet in length. Loaded vessels have entered or left the harbor of New York with a draft of 32 or 33 feet and possibly a little more. For these general reasons the former Commission prescribed a bottom width of 150 feet for the canal and a depth of water of 35 feet. Although it is not probable that the greatest ships afloat will, immediately after its completion, seek the Panama Canal, it is practically certain that the opening of such a canal will shift some lines of ocean traffic and stimulate others, so that it is a measure of wisdom only to follow the instructions given to the former Commission and tacitly at least to the present Commission, to construct a waterway which shall afford accommodation for the largest ships afloat.

The Panama Canal line will be practically identical with that first adopted by the old Panama Canal Company and subsequently accepted by the new Panama Canal Company. There will certainly be some modifications of details of alignment, but in the main the French location was well considered, and the canal will be built upon it. There is still an open question as to the advisability of what is known as the Tiger Hill alternative, which was so strongly advocated by the late Mr. George S. Morison, member of the former Commission. This alternative line was originally surveyed and located by Commander Lull, U. S. Navy, in 1875. It covers that portion of the canal location between Gatun, about 6 miles from Colon, and Bohio, about 17 miles from the same point. It is a shorter line than the French location by about 1¼ miles. It also has the advantage of moving the canal line away from the Chagres River to the foot of the high ground easterly of that river and throughout a portion of its length materially higher than the low marshes along the course of the river. It has two disadvantages: One, that the excavation of the old Panama Canal Company between Gatun and Bohio would be abandoned, necessitating a correspondingly increased amount of new excavation; and the other, that the canal prism would be carried for a considerable distance between Tiger Hill and Bohio within an embankment attaining a height in some places of nearly or quite 20 feet and resting on soft ground. The necessary data for the determination of this and other features of modified alignment have been already largely secured, enabling such questions to be satisfactorily answered in the near future.

The total length of the Panama Canal between 6-fathom curves in the two oceans is 49.09 miles, of which about 17 miles on the Caribbean side and 8½ miles on the Pacific side, i. e., practically one-half the length of the canal, is to be excavated through low, marshy ground little above sea level. These two portions of the line constitute the Atlantic and Pacific sea levels in the plans of the new Panama

Canal Company as well as of the former Isthmian Canal Commission. This is an important feature of the project, especially in considering ultimately whether a sea-level canal or canal with locks shall be built, for it indicates that in any event a little more than one-half of the canal will be a sea-level waterway. Will it, then, be advisable to give to the remainder (less than half the length) the same freedom from restriction of locks to navigation?

The intermediate 24 miles of canal line cover the higher portions of the low saddle in the Cordillera at the Panama crossing. The highest point in this saddle before any excavation was made at Culebra was about 330 feet above mean sea level. The length of this deepest canal cutting through Culebra Hill is scarcely 3,000 feet. Strictly speaking, the heavy part of the summit cut, comprising what is ordinarily known as the Emperador and Culebra cuts, is not more than 6 miles in length, and its original surface elevation, with the exception of the Culebra portion, averages about 175 feet above mean sea level. The natural slope from the Culebra Cut toward the Pacific is relatively abrupt, it being but 4 miles from the cut to Miraflores, at which both the former Commission and the New Panama Canal Company located their first lock on the Pacific side of the Isthmus. The slope from the northerly end of the summit cut at Emperador toward the Caribbean is relatively gentle, the distance from Emperador to Bohio, where the New Panama Canal Company and the former Commission located the first lock on the Caribbean side of the Isthmus, being 16 miles. No well-developed plans for either of the terminal harbors have been made up to this time, but such plans are now being thoroughly considered by the present Commission.

The Old Panama Canal Company, which began its operations in 1881, planned a sea-level canal having a depth of water of 29.5 feet, and bottom width of 72 feet. It carried on work actively until 1889, when it suspended operations and went into bankruptcy, its excavations amounting to a total of about 72,000,000 cubic yards. The New Panama Canal Company has excavated about 8,000,000 cubic yards since that time. The work of excavation of the old company was distributed over parts of the entire line, although there were considerable portions of the line on which no excavation at all was made. Over some other portions of the location relatively small quantities of material only were taken out. The largest parts of this work were performed within about 12 miles of Colon, within about 5 miles of Panama, and within a distance of about 7 miles, including the great Culebra and Emperador cuts. The excavation along the sea-level portions of the canal at either end was all made in soft ground, but in the excavation in the Emperador and Culebra cuts, as well as at Obispo, near the point where the Chagres River

first cuts the line of the canal as it flows toward the sea, considerable rock was found, some of it being dense and hard. In addition to this work of actual excavation, the French companies, especially the New Panama Canal Company, accumulated a large amount of available information regarding the subsurface material and depth of bed rock at many points along the line. The examinations, including jet borings at the proposed Bohio and Gamboa dam sites and for the proposed dam at Alajuela higher up the river, are included in this portion of their operations. The performance of this large amount of excavation work and the investigations disclosing information regarding the subsurface materials have largely revealed with certainty the character of the greater part of the work to be done in completing a ship canal. In other words, they reduce materially those exigencies of such a great work which consume time and add to the cost.

Of the total excavation hitherto made and amounting to about 80,000,000 cubic yards, probably not more than one-half will be available in the construction work to be planned by the present Commission. This, however, constitutes an available asset of much value.

There is another asset, available to an uncertain extent, in the immense quantity of material and plant, left largely in well-kept warehouses but otherwise spread along the entire line in an exposed condition. The apparent book value of all this material, as shown in the records of the New Panama Canal Company, is about $29,000,000. By far the greater part of this value is now imaginary only. A considerable part of the plant and a large amount of the material in the warehouses can, however, be brought into condition of much value as the work progresses. Indeed, several of the old bucket dredges, a large number of dump cars, and various other plant, including a most useful machine shop at Matachin, have already been repaired and put into service by Mr. John F. Wallace, the chief engineer of the Commission. The present Commission has thus come into control of a great ship-canal work, a small portion only of which has been performed, and with the greater part of the data required for the ultimate solution of all its problems yet to be determined. These problems include, first of all, the answer to the main question, whether the canal shall be a sea-level canal or of the lock type. Whether one type or the other be adopted, they cover also such great features of the work as the interior harbor at the Colon or Cristobal entrance to the canal and possibly the exterior harbor lying outside of it; the control of the Chagres River in times of flood, involving the construction of probably a great dam at Bohio or at Gamboa and possibly a tunnel through the Cordillera to divert the waters of the Chagres River toward the Pacific Ocean; additional harbor facilities at the Ancon or Panama end of the canal; the eleva-

tion of the summit level if a canal with locks should be built, and the number, location, and lift of those locks. Manifestly, the solution of some of those problems must depend upon the rate at which excavation can be made, either in rock or in earth, and its unit cost. Further than this, in the event of building a lock canal, it is highly probable that a great dam will be required across the Chagres near Bohio, whose construction would involve unprecedented methods upon a large scale in consequence of the great depth of bed rock at that place.

Preparation for construction was begun by the Commission last May by organizing engineering field parties which sailed from New York during June and the early part of July. At the same time Mr. John F. Wallace, formerly general manager of the Illinois Central Railroad Company, past president of the American Society of Civil Engineers, was appointed chief engineer of the Isthmian Canal Commission, and he entered upon his duties the latter part of June. There were five of these parties, besides the engineering force organized for the purpose of designing and constructing waterworks and sewer systems for the cities of Panama and Colon.

Taking these forces in the order of their location from Cristobal, the American port at the Caribbean end of the canal, the first is located at that point. This party is charged with the duty of making all the requisite surveys and investigations, including jet borings, both on land and water, needed for the development of the complete plans for the interior harbor at the mouth of the canal, for the deep-water channel leading to it from the harbor of Colon, and for any advisable realignment of that portion of the canal between Cristobal or Colon and Gatun, about 6 miles inland. The second party was intrusted with the surveys and investigations required to determine the feasibility of building a dam across the Chagres Valley at Gatun and to ascertain whether it is desirable to confirm the location of the French companies between Gatun and Bohio or to adopt the Tiger Hill alternative between those points. The third party has undertaken to make exhaustive investigations, including surveys, necessary for the location of a dam across the Chagres near Bohio, also to make certain other surveys connected with some minor details of relocation in the same general vicinity. This party is making many jet borings on a number of profiles, so as to secure complete information regarding the deep bed rock under the river. In this manner the most favorable location for the Bohio dam, should it be constructed, may be conclusively determined. The fourth party has been assigned to the responsible duty of making extensive surveys and other investigations from Gamboa, where the Chagres River and canal line intersect, about 30 miles from Colon, 12 miles or more up the Chagres Valley. This work will cover the continental divide

at the summit of the Cordillera, the southerly limit of the Chagres watershed, and the divide constituting the northerly limit of the same shed; it will include also the numerous borings to bed rock at the Gamboa dam site and at other points. It will disclose the information requisite for the determination of plans for effectively controlling the flood flow of the Chagres River. The data already obtained show that it is entirely feasible to build a dam at Gamboa and to divert a portion or all of the waters of the Chagres to the Pacific through a tunnel not more than 7 miles long, or toward the Carribbean Sea through a tunnel piercing the other divide and about 4 miles long, the former probably being preferable. The surveys of the French companies failed to disclose any location for a tunnel less than 10 miles long through the Cordillera toward the Pacific.

The New Panama Canal Company had a labor force of about 700 men engaged in excavation at the great Culebra Cut when the canal property was turned over to the present Commission in May last. The organization of this force and plant has been maintained and greatly increased in efficiency. The fifth field party was assigned to such engineering work in connection with this great excavation as will be required for its ultimate execution and in making the final location in the vicinity of Culebra. This force has also been instrumental in installing a system of field accounts, so that a complete daily record may be kept of progress and cost of all classes of work.

All of these parties have conducted the operations assigned to them continuously and energetically. They have secured data of great value in the ultimate solution of the main problems of the project. They are still at work in their several fields, but these preliminary operations are drawing to a close, thus enabling the Commission promptly to study and formulate the final plans on which the work of construction on a large scale depends.

The United States Government is required under the treaty made with the Republic of Panama not only to construct complete water works and sewer systems for the cities of Panama and Colon, but also to formulate and execute certain sanitary measures for those cities. In accordance with the terms of the agreement recently reached by Secretary Taft with the Panama Government at the city of Panama, complete control of this sanitary work has been vested in the United States Government represented by the Isthmian Canal Commission.

The source of public water supply selected for the city of Panama is a reservoir in the upper Rio Grande Valley close to the great Culebra Cut and about 10 miles from the city. The dam for this reservoir was constructed in the days of the old Panama Company by M. Philippe Buneau-Varilla, chief engineer, and subsequently the first minister plenipotentiary from the Republic of Panama to the United

States. This is an interesting example of a curved concrete dam built in a few days' time and containing little masonry, yet it has proved admirably adapted to its purpose. This dam will be raised and strengthened so as largely to increase the capacity of the reservoir. A 16-inch cast-iron pipe will convey the water to a distributing reservoir at Ancon, in the Canal Zone, at a suitable elevation on the northeastern slope of Ancon Hill immediately adjacent to the city of Panama. The supply has been based upon an estimated daily consumption of 60 gallons per head of population. The distribution system is complete in every particular and adapted to any extension required by the future growth of the city. The construction of this waterworks system has progressed so far as to render it practically certain that the city will receive the first public water in its history in February next.

The planning and construction of the sewer system has also been pushed forward as rapidly as possible and it will be completed ready for use soon after the introduction of water. The sewer system is divided into three districts, each having an outfall into the sea water of Panama Bay, at a sufficient distance from the shore to provide abundant dilution. The system is designed to receive the sewage of the city and a rainfall of about 1 inch per hour, any excess over the latter being carried off on the surface. When it is remembered that the city of Panama has never before had a sewer system it can readily be appreciated what a sanitary relief both the sewer system and the water supply will be to the city.

The water-supply and sewer systems for the city of Colon have also received the careful attention of the Commission. A suitable source of water, however, has not been so easy to find as at Panama, and the sewer system can not be constructed until a considerable amount of filling with excavated material from the canal has been completed. Both works, however, will be undertaken and finished in the near future. As the population of Colon is under 6,000, while that of Panama is nearly 20,000, the conditions bearing upon the sanitation of Colon are the more easily controlled pending completion of its waterworks and sewers.

It may be interesting to observe, although not in line with the actual construction of the canal, that the Commission among its other duties is charged with that of the civil government of the Canal Zone, a territory 10 miles wide, running across the Isthmus with the axis of the canal as its center line, but excluding the cities of Panama and Colon as delimited under the treaty. Maj. Gen. George W. Davis, U. S. Army, retired, member of the Isthmian Canal Commission, is the governor of the Zone, and under his jurisdiction have been organized by the Commission most effective hospital and sanitary forces, with Col. W. C. Gorgas, U. S. Army, as chief sanitary officer. The

great hospital on the slope of Ancon Hill, with its 700 beds, has been put in excellent working condition, while the sanitary forces of the Commission have already rendered highly effective services toward bringing the entire Zone into sanitary condition, especially in the extermination of mosquitoes. Boards of health of high character and excellent quarantine organizations have been established both at Panama and Colon. Although four sporadic cases of yellow fever have occurred in Panama within the last six months, the infection has not spread from any case, in consequence of the vigilance of the medical and sanitary forces. The general health of the Isthmus has been good and there seems to be a certain promise of excellent sanitary conditions hereafter, such as to enable the forces of the Commission to perform their work in safety from epidemics and with the highest degree of efficiency obtainable in the Tropics.

SANITATION OF THE PANAMA CANAL ZONE.

By Col. W. C. Gorgas, U. S. Army,
Chief Sanitary Officer.

From a sanitary point of view the location of the Panama Canal is very important. It is within the limits of the Republic of Panama. in the Tropics, and about 9° north of the Equator. For engineering reasons the lowest point in the mountain range, running north and south through the Western Hemisphere, has been selected, the range at this point being about 300 feet high. The Isthmus, in its general direction here, runs east and west; the canal, therefore, in a general direction is north and south. The local coast line at the point where the town of Panama is situated bellies somewhat toward the south, so that when you look to the east you see nothing but the Pacific Ocean as far as the eye can reach. It struck me with surprise and took me some time to get used to the phenomena of every morning seeing the sun rise out of the Pacific and set behind the mountain on which I live. My preconceived ideas were just the opposite—that is, that the sun should rise out of the Atlantic and set in the Pacific. As a matter of fact, the town of Panama is some 20 miles east of a line drawn north and south from the town of Colon.

The town of Panama was established early in the sixteenth century, and was probably selected because the ridge of the hemisphere was lowest at this point and because the Chagres River gave river transportation at this point about two-thirds the distance across the Isthmus. The Isthmus is narrower, considerably, at several other points than at Panama; but the ridge at these points is very much higher. The town rapidly grew in importance, and in the first hundred years after its settlement was probably the most important town in Spanish America. Here Pizarro's expedition was fitted out, and here all the enormous gold and silver treasure from the South American conquests came across the continent. In 1671 the English buccaneer, Henry Morgan, captured and sacked the city after he had outmaneuvered and defeated a larger and superior Spanish regular force on the broad savannas adjacent to the town. After this catastrophe the present location of Panama was selected—a high penin-

sula running south into the Pacific and easy of defense. It was so strongly fortified that no attempts thereafter were made to carry it by storm. It stands about 6 miles west of the site of the old town, of which abundant ruins are still visible.

In former days a good paved highway ran straight north through the mountains toward the convenient port of Puerto Bello, but when the railroad was constructed the northern terminus was located at the present town of Colon. The line of the canal, so far as it is at present fixed, runs about 50 miles north and south, between the port of Colon on the north and Panama on the south. It follows in general, beginning from the northern end, the valley of the Chagres River and one of its branches—the Obispo—up to the top of the divide at Culebra, some 35 miles, and then down the valley of the Rio Grande to Panama, some 15 miles. Contrary to the general impression that I had formed before coming down, the country is rolling and well drained, being essentially a mountainous district. The Chagres, of course, has marsh and lowlands in its valley, but no more than half the smaller rivers and larger creeks of the mountainous districts of Alabama or New York. The country in general is very attractive, high and variegated as it is, with rolling hills and tropical verdure as far as the eye can reach. Insects and reptiles are scarce, and our friend, the mosquito, could not be called abundant. I believe any dweller of Staten Island or New Jersey, after a week's residence, would leave with the impression that there were none of the latter.

For purposes of canal building the United States has purchased a tract of land extending along the whole length of the line of the canal 10 miles in width, of which the canal is in the center. The history of this Zone with regard to health has been exceedingly lugubrious, just as it has occurred everywhere else in the Tropics or wherever a large, unacclimated population has been brought in, either for military or industrial purposes. The railroad was built in the early fifties, and its cost was greatly increased and the work itself several times stopped on account of the heavy mortality among the unacclimated laborers brought here. Later, between the years 1880 and 1889, the same thing occurred on a much larger scale in the French attempt to dig a canal under De Lesseps. The diseases causing the most mortality at these times were yellow fever and malaria.

At the present time on the Zone there are 40,000 inhabitants, Panama containing 20,000, Colon 10,000, and the towns along the canal between Panama and Colon 10,000. The prevailing disease is malaria. Leprosy also exists. In Panama we have at present some yellow fever and a great deal of beriberi, and, of course, all other

tropical diseases to a limited extent. Eighteen months from the present time, I am informed by the chief engineer, we will probably have on the Isthmus a force of some 15,000 men. Estimating from our present ratio, I am inclined to think that not more than 2,000 of these will be Caucasians and the other 13,000 negroes. Now, the sanitary problem will be to protect these 15,000 men from malaria and from yellow fever. I will take up first yellow fever. I assume it as accepted that it is conveyed from man to man only by the female *Stegomyia*, who has previously bitten some human being suffering from yellow fever. Therefore, given a place in which there are no infected *Stegomyia*, yellow fever can not originate until a human being suffering from yellow fever has been introduced and infected the local *Stegomyia*, or unless the female *Stegomyia*, infected at some distant point where yellow fever prevails, has been introduced. Practically the first is almost the only method of infecting a locality—namely, the introduction of a human being suffering from yellow fever. The city of Panama has been in the condition for a great many years of at all times having within her borders some infected *Stegomyia* at all seasons of the year, and the nonimmune foreigner coming within her limits is liable to contract the disease. Yellow fever is at present endemic nowhere on the Zone except in the city of Panama. The object of the sanitarian is, therefore, to get rid of the infected *Stegomyia* at present existing in the city, and this can be done in this way: Establish a system whereby the health authorities will pretty certainly be informed of every case of yellow fever occurring; then take the house in which this case occurs and fumigate it, so as to destroy all the mosquitoes within its borders. Do the same with all the contiguous houses.

This, it has been found by experience, kills all the infected mosquitoes at that particular focus. The same thing is done at every other focus as yellow fever occurs. Gradually, in this way, all the foci in the community are destroyed; and when you have destroyed your last focus yellow fever is at an end. Or, if you want to be more expeditious and the town is not too large, you can systematically fumigate every house in the town, and thus pretty certainly destroy all infected mosquitoes and do away with yellow fever much more rapidly. But no system of reporting is ever absolutely certain and the sanatarian should see that other very important adjuncts to the fumigation work are carried on at the same time. The Stegomyia is a house mosquito and cleanly in her habits, seeks principally clean rain-water barrels and water containers, and lives very close to her birthplace, not traveling far. Therefore, as an additional sanitary safeguard, every receptacle for water should be so screened and covered that mosquitoes can not have access. All

yards should be thoroughly cleaned, so that there will be no old bottles or cans left around. The water supply should be piped in, so that the people will not desire to have water in containers. Sewers should be put in, so that there will be no excuse for people to throw slop water in the yards. All standing puddles should be drained and kept dry. Streets should be paved and kept well swept, and the garbage carefully collected, with a view to decreasing to the minimum all trash capable of retaining fresh water in any way. When Panama has been in this state for a month or two we will be in the same condition that Habana is, as the result of just such operations as I have described above. When Panama has thus been freed from yellow fever we will not have any more until a man sick from yellow fever is introduced from some infected point without. This we will prevent by a proper system of quarantine, just as Habana has done for the past three years.

Thus I can see the entire possibility of protecting our laborers on the canal during the whole time of its construction from one of the two greatest causes of former mortality.

But I think that probably a more important problem for the health of our laborers, and certainly a much more difficult one to deal with, is that of malaria along the line of the canal. The 10,000 natives living along the canal are distributed in about 20 small villages. These people are very generally infected with malaria. A recent microscopical examination of the blood of people, taken at random at various points along the line, in several hundred cases showed parasites in the blood of 50 per cent of these people on the first examination. This means pretty certainly that about 80 per cent of the natives at the present time have the malarial parasite in their blood. Four times out of five, when a female Anopheles bites one of the natives she becomes infected, and when she, in turn, bites one of our nearby laborers he becomes infected. It is thus evident that our force will rapidly be used up, just as was the French, unless our sanitary measures prevent it.

Now, we can approach this problem from two sides; either on the side of doing away with the infected human being so that he can not infect the mosquito, or doing away with the mosquito so that she can not transmit the parasite from the diseased to the well. If we could kill these 10,000 natives and keep our laborers away for four or five months until all previously infected mosquitoes had died, the problem would be settled; but our superiors would very properly not sanction this very drastic measure, even if proposed by us. But if we have some substance which could be introduced into the circulation of the infected man, and kill the parasite and at the same time not be injurious to man, we would accomplish the same object just

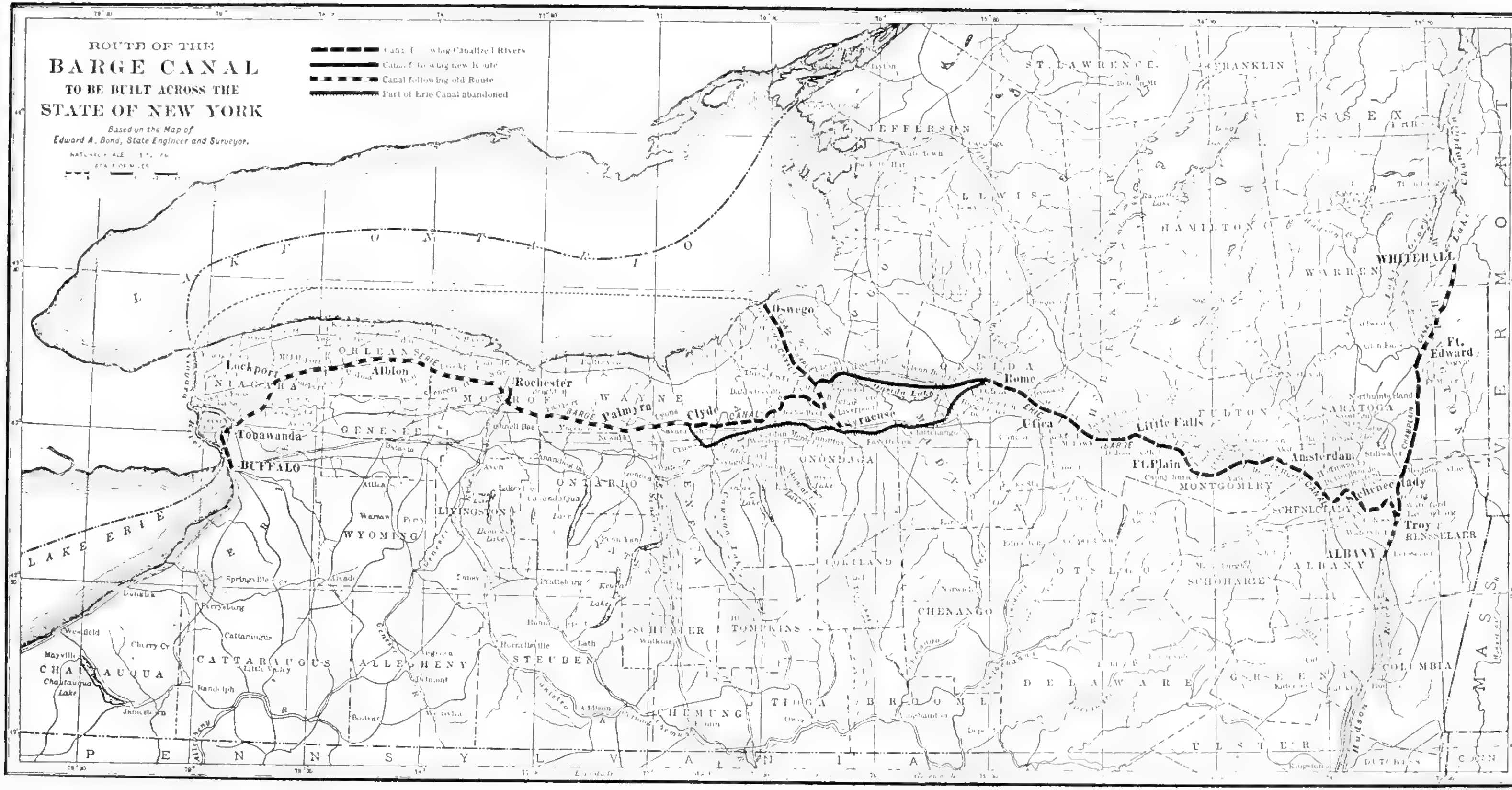
as effectively as if we killed the man, and the measure would not meet with such general opposition as the former proposition would. In quinine we have discovered this poison. This vegetable substance is harmless to man and fatal to the malarial parasite. The greater number of practical tropical sanitarians, the Germans and the Italians conspicuously, advocate and have been successful on these lines—have gotten as large a proportion of the population as possible to take small quantities of quinine with as much regularity as they could; and thus have been successful, without adopting any other measures, in doing away with malaria in the several localities. Or, we can attack it from the side of the mosquito; do just what we intend doing in Panama with regard to the Stegomyia: Cover all water containers, clear up the yards, fix the roads so there will be no puddles, have a regular system in all the towns of collecting garbage and waste so there will be no cans around; and ditching everywhere there are small breeding places in the neighborhood of dwellings, and oil where ditching is not practicable. This latter method of killing the mosquito is the method most in favor by English and American tropical sanitarians. This alone has been successful in eradicating malaria in many localities.

Along the route of the Panama Canal the malaria problem, I think, is more difficult to deal with and more serious than any place where it has previously been tried. We therefore expect to adopt both methods, and I am convinced that in this way we will be able to protect our laborers from the serious mortality that has undone our predecessors in this important work.

The other diseases to which we are subject, I think, will not give us serious trouble, but will be controlled by the ordinary measures usually adopted by a health department.

ANCON, ISTHMIAN CANAL ZONE,

February 10, 1905.


ROUTE OF THE
BARGE CANAL
TO BE BUILT ACROSS THE
STATE OF NEW YORK
Based on the Map of
Edward A. Bond, State Engineer and Surveyor.
Canal following old Route
Part of Erie Canal abandoned
LAKE ONTARIO
LAKE ERIE
BARGE CANAL
Buffalo
Tonawanda
Lockport
Albion
Rochester
Palmyra
Clyde
Syracuse
Oswego
Rome
Utica
Little Falls
Ft. Plain
Amsterdam
Schenectady
Troy
Albany
Ft. Edward
Whitehall
PENNSYLVANIA
VERMONT
MASS.
CONN.
NIAGARA
ORLEANS
MONROE
WAYNE
ONEIDA
FULTON
SARATOGA
MONTGOMERY
SCHENECTADY
RENSSELAER
ALBANY
SCHOHARIE
OTSEGO
CHENANGO
CORTLAND
TOMPKINS
ONONDAGA
ONTARIO
LIVINGSTON
WYOMING
GENESEE
CATTARAUGUS
ALLEGHENY
STEUBEN
SCHUYLER
CHEMUNG
TIOGA
BROOME
DELAWARE
GREENE
COLUMBIA
ULSTER
JEFFERSON
LEWIS
ST. LAWRENCE
FRANKLIN
ESSEX
HAMILTON
WARREN
CHAUTAUQUA
Chautauqua Lake
Oneida Lake
Hudson

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THE PROJECTED NEW BARGE CANAL OF THE STATE OF NEW YORK.[a]

By Col. Thomas W. Symons, U. S. Army.

In the years following the Revolutionary war the subject of navigable canals was a very absorbing one to our forefathers. In this new and rapidly developing country in those pre-railroad days the importance of canals in the transportation world can hardly be appreciated at the present time. Canals were projected all over the country, and many were built. The attention and labors of the ablest men of the period were devoted to canal schemes, their financing, locating, and building.

A good many of the canals that were built have succumbed to new conditions and been discontinued, being unable to stand the competition of railroads. Some, however, have stood the test of time and have remained important factors in the commercial world to the present day. Without question the most important of these early artificial waterways was the Erie Canal through the State of New York, connecting the Hudson River with Lake Erie. This canal, although originally built of small size, played a very important part in the settlement of the great West, or what was then the great West, by furnishing a route in connection with the Great Lakes by which the products of the new western country could reach the markets along the seaboard, and by which in turn it could get its supplies of clothing, tools, groceries, etc., at an economical rate for transportation. It is certain that the settlement and development of the New York and New England hinterland were enormously expedited by the Erie Canal.

Locally in New York State the effect of this canal was shown by the increasing commercial importance of New York City and the establishment and development along the line of the canal of the most important chain of cities in the country—Albany, Troy, Cohoes, Schenectady, Little Falls, Utica, Rome, Syracuse, Rochester, Lockport, and Buffalo.

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[a] Reprinted, by permission, from the Bulletin of the American Geographical Society, May, 1904.

Some of the early New York canals have been abandoned. Those which are left and kept in a navigable condition are: the Erie Canal, connecting the upper chain of Great Lakes above Niagara Falls with the Hudson River, and thence with the seaboard; the Oswego Canal, which connects Lake Ontario with the Erie Canal, and the Champlain Canal, which connects Lake Champlain with the navigable water of the Hudson. The Erie Canal, which is the principal member of this canal trinity, is 350 miles long, and at present has 72 locks. It was originally built with a depth of 4 feet, with locks 90 by 15 feet, being of a size to accommodate boats of but 80 tons capacity, and was completed in 1825. Tolls on the canal were high at first, but were gradually reduced, and for many years have been abolished altogether.

It is a noteworthy fact that before they were finally abolished the tolls had more than paid for the canals of the State and their enlargement.

The small 80-ton canal was soon found inadequate, and it was enlarged to its present capacity—that is, for boats carrying 240 tons of freight. This work of enlargement was started in 1835, but was not completed until 1862.

When the canal was built, and when it was enlarged, the only known or successfully developed method of canal-boat propulsion was by animal towing, and a tow path was provided all along the canals. The necessity for this tow path was one of the principal factors which caused the canal to be kept out of water courses and built in the upper portions of the valleys. The development of steam canal-boat propulsion has changed the problem, and the great canal that New York is to build will now be located, wherever possible, in streams and lakes, and it will have no towpath. This will reduce the cost of maintenance enormously, for the cost of keeping the towpath in order is the heaviest item of expense of the present canal.

The New York canals were no sooner enlarged to their present size than agitation for their further improvement commenced. This culminated, about ten years ago, in the adoption of a project for deepening the canals so that they would accommodate boats of 8 feet draft instead of 6 feet, and for lengthening the locks so that they would take two boats of the same length and width as at present, coupled tandem, at one lockage. The State made an appropriation of $9,000,-000 to carry this project into effect. It was soon found, however, that the amount named was grossly inadequate, and that to complete the project would cost two to three times the sum which had been voted. The work was also badly managed, and the people of the State were indignant at the deception which had been practiced on them regarding the estimates and the scandals attending the work, and the project was abandoned. Then came another period of agitation, investiga-

tion, and discussion. All sorts of things were proposed. Many prominent people wanted a ship canal connecting the Great Lakes with the sea, and several routes were surveyed, and estimates of cost of various sized canals made. Many wanted the $9,000,000 project completed, either as originally proposed or with modifications. Some wanted to turn the State canals over to the General Government, and depend on it for maintenance and improvement. Some wanted to abandon the canals altogether, and some to utilize the canal right of way for State railroads.

In 1897 the writer of this paper, in a report to the General Government, proposed, as the best solution of the problem, that the canals should be enlarged to enable them to be used by barges carrying 1,000 to 1,500 tons. Governor (now President) Roosevelt appointed a board of prominent New York business men soon after this to advise the State what to do with its canals, and this board, after more than a year of investigation, and the careful consideration of everything that could be proposed, reported in favor of enlarging the Erie Canal to a capacity for barges of 1,000 tons, and a lesser improvement for the Oswego and Champlain canals. The legislature caused surveys, plans, and estimates for the work to be made. All the canal people of the State finally came in under the banner of the 1,000-ton barge canal, and through their united efforts the legislature at last passed a bill for the enlargement of the Erie, Oswego, and Champlain canals, to enable them to be used by 1,000-ton barges, with all the locks of sufficient size to take two boats, coupled tandem, at one lockage.

The estimated cost of the work proposed was $101,000,000. At the fall election of 1902 this proposition was submitted to the people of the State, who approved it by a majority of about 250,000 votes.

New York is thus committed to and has entered upon this tremendous work of canal improvement—by far the greatest work ever undertaken by any State.

This projected work is in the very front rank of canal propositions. It is overshadowed in the public mind by the Panama Canal, on account of the international character and the interesting complications that have attended the inauguration of that work by the United States. In commercial importance the Erie is in many ways the equal of the Panama Canal. On the Panama it is hoped to some time reach a tonnage of 10,000,000; on the Erie all works, structures, water supply, etc., are predicated on a tonnage of 10,000,000, and provisions are made for accommodating, at slight additional expense, a tonnage greatly in excess of this. On the upper Great Lakes there is a water-borne commerce of very nearly 90,000,000 tons per year. The Erie Canal will furnish the cheapest route for connecting this

vast lake commerce with the seaboard, and its wide-reaching influence can hardly be conceived or appreciated except by those who have given years of study to the problem.

In magnitude the work that New York has undertaken exceeds the work at Panama. More earth and rock must be excavated, more masonry used, and more dams built. The cost per unit is not nearly so high as at Panama, because the work will be done in the Temperate Zone, where labor, tools, and materials are abundant and reasonably cheap.

In the complexity of the engineering questions involved the Erie is hardly second to the Panama Canal, for while the canalization of the Mohawk River is a very different problem from the control and utilization of the Chagres River they are both engineering projects of the very first magnitude.

The building of the Panama Canal under conditions akin to the proposed enlargement of the Erie Barge Canal would be a simpler, cheaper, and easier work than that which New Yerk has undertaken.

The barge canals that New York is to build will follow the same general route, fulfill the same functions, and minister to the same wants as the present navigable canals connecting Lakes Erie, Ontario, and Champlain with the navigable waters of the Hudson below Troy.

In three important respects they will differ from the existing canals: First, as to size and capacity; second, as to location, and third, as to the character of navigation provided for.

The locks of the new canals, which govern the dimensions of the boats that can be used, are 28 feet wide, 310 feet long, and 11 feet deep. The canal prism has a depth of 12 feet and a general minimum width on the bottom of 75 feet in canal sections and 200 feet in rivers, pools, and lakes. Boats can be built which will pass through the canal carrying 1,000 tons of freight, but it will probably be found advantageous to sacrifice some of the carrying capacity to secure better models and greater clearance. The lift of the locks will be much greater than at present, and the number of locks will be greatly reduced. On the present Erie Canal there are 72 locks; on the new Erie Barge Canal there will be but 38 locks.

The new locks will take two canal boats, each of 150 feet length, coupled tandem, at one lockage, and this makes the lock capacity 2,000 tons, or about eight times that of the present canal. As freight boats nearly always travel in pairs coupled tandem, the advantage of the double-length locks in doing away with the necessity of uncoupling and recoupling at every lock is very great, saving much time and lessening dangers.

A very decided change is made in the location of the canals. The Erie Canal is about 350 miles long, and the new canal follows the old canal for only about 100 miles; the other 250 miles is almost entirely

by a new route. Large portions of the Champlain and Oswego canals also follow new locations.

The existing canals may be called "hillside" canals, as they go through the open country and along the upper portions of the valleys above the rivers, from which they religiously keep away to the greatest extent possible. The new and greater canal is put in the valley bottoms and in the water courses and lakes wherever practicable.

The principal advantages of the valley-bottom location in the case of the greater canal are cheapness of construction, greater freedom and ease of movement by boats in the wider waters of the water courses and lakes, greater rapidity and less cost of transportation, greater immunity from accidents that disable the canal, and less cost of maintenance. With the small canal as originally built and as subsequently enlarged to its present size it would not have been economical, with the knowledge and means then possessed, to have built the dams and locks required to canalize the Mohawk and other rivers and to excavate the large channels required for flood discharge. With the large barge canals now proposed this canalization is not only desirable, but is cheaper than it would be to utilize the existing lines of the canals.

The existing canal is a "tow-path" canal, built with the distinct idea that all business on it should be done by animal towing. In the new and larger canal no tow path is provided, and it is expected that navigation through it will be by means of steamboats properly adapted to it and towing other motorless cargo boats, in accordance with the custom which has been developed and is now in vogue on the Erie Canal to a certain extent. It is this change in the method of navigation which permits the valley bottom, lake, and water-course location to be adopted.

Long years before the construction of the Erie Canal the early pioneers had found a water highway extending nearly acreoss the State of New York, and it was largely used by those who settled the western portion of the State. It was not perfect, involving, as it did, many portages about falls and rapids and from one river to another, and the stemming of swift river currents, with bars and shoals, but it fulfilled a most useful function.

The Erie Canal when built did not follow this pioneer route for reasons stated; but it is a remarkable circumstance that now, after nearly a century of disuse, this old pioneer route is to be again adopted and the new and larger barge canal is to follow it without material deviation. This old pioneer route followed up the Mohawk River, with portages about the falls and bad rapids, to the vicinity of Rome; thence a portage was made across to the waters of Wood Creek; thence it followed down the waters of this small stream to Oneida Lake. On across the lake it went and down the Oneida River

to the junction of the Oneida, Oswego, and Seneca rivers, at Three River Point—a famous locality in the olden days. Here two routes were open to the enterprising traveler. If he were going to the settled western part of the State he would follow up the Seneca River and thence into the various branches and into the beautiful "finger" lakes tributary to the Seneca. At that time and by that route the cost of transportation between Albany and Seneca Lake was from $75 to $100 per ton, and it took four weeks to make the round trip. If he were going farther west, or into Canada, or had much freight to transport, he would ofttimes go on down the Oswego River to Lake Ontario and thence by lake to his destination.

The projected route of the Erie Barge Canal follows up the Hudson River to Waterford; thence, by means of the requisite locks, it reaches the Mohawk River above Cohoes Falls. From Cohoes Falls to just west of Rome the river is canalized—that is, dams are built, forming great pools, and these pools are connected by channels not less than 200 feet in width and 12 feet in depth. Above Rome there is a summit level leading over to Wood Creek, and, as in the olden days, the canal route follows down this stream and through Oneida Lake and Oneida River to Three River Point, thence up the Seneca River properly canalized to the vicinity of Clyde. From Clyde westward there are no water courses of importance running in the right direction, and the new canal will follow generally the route of the existing canal to the Niagara River at Tonawanda; thence the Niagara River will be used up to Lake Erie and Buffalo. Between Clyde and Tonawanda there is one important modification of the route, and this is at Rochester. The present canal goes through the city in a very awkward manner, crossing the Genesee River in a masonry aqueduct, and the route is impracticable for the large canal. Here a new route is adopted, passing to the south of the city and crossing the Genesee River in a pool formed by damming the river.

The Oswego Barge Canal leaves the Erie Canal at Three River Point and keeps on down in canalized Oswego River to Lake Ontario.

The new Champlain Canal keeps in the Hudson River from Waterford to Fort Edward, instead of following along on the bank of the river as at present. In doing this advantage is taken of the commercial power dams which already exist in the river, and which, in connection with locks to pass them and the deepening of the river between the pools, will fully canalize the river. From Fort Edward to Whitehall, at the foot of Lake Champlain, the new canal follows the location of the existing one.

The most important question connected with any canal proposition is that of water supply, and the Erie Canal is no exception. The western end of the canal will be fed from Lake Erie, as at

present, the existing canal from Lake Erie to Tonawanda being retained as a water feeder only. This, with natural local supplies from streams along the line, will give all the water required until the Seneca River is reached, which has an abundance of water. The only locality where the water-supply problem attains great importance is at the summit level, between the Mohawk River and Oneida Lake. This is provided for, in the larger canal, by utilizing the existing sources of supply and developing additional ones by water storage in West Canada Creek, the Mohawk River, and Oriskany Creek.

If in the future more water is needed, due to increased use of the canal, or for any other reason, this can be supplied by additional storage in the Adirondacks at a comparatively small expense.

It is believed that these new and enlarged canals will be of benefit to New York in enabling her to retain and increase her commercial supremacy, largely through their controlling influence on freight rates and the prevention of differential discrimination against the port of New York, which is now and has for years been the rule.

They will also benefit the entire region of the Great Lakes, and this benefit will extend far into the interior of the great Northwest and influence transportation rates throughout the country.

Upon the Great Lakes many millions of tons of freight are transported every year at exceedingly low rates—far lower than are possible by any other than water transportation. The canals that New York has undertaken to build will practically extend this cheap system of water transportation to the seaport of New York and other ports in the vicinity, and bind the East and West closer together.

RAPID-TRANSIT SUBWAYS IN METROPOLITAN CITIES.[a]

By Milo R. Maltbie.

The problem of urban transportation is largely one of rapid communication between business and residential districts, and has grown increasingly difficult as population has become more and more concentrated. Street-car companies have tried every conceivable kind of motive power, but they have not been able to keep up with the rapid growth. Steam railroads, which have proved so successful as interurban means of communication, have been excluded from most centers because of the noise, smoke, and ugliness of the trains. Horse traction is not sufficiently rapid, and the cable for the same reason has given way to electricity.

However satisfactory surface lines may be for short-distance traffic, their inadequacy to deal with suburban traffic became apparent almost half a century ago in the larger urban centers. The steam roads undertook to solve this question by lowering fares and by greatly increasing the number of trains. London went a step further and built underground roads connecting most of the depots in the metropolis. Other cities, such as New York, Chicago, Boston, Liverpool, and Berlin, have constructed elevated roads, but these are unsightly, and within the last few years they also have proved or are proving inadequate to deal with the vast throngs who daily leave their homes to seek work in other portions of the cities in which they live. And now, as the last resort, electric subways are proposed, and systems have been or are being built in Paris, Budapest, Glasgow, London, Boston, and New York,[b] while other cities are considering the question.

[a] Reprinted, by permission, from Municipal Affairs, New York, Vol. IV, No. 3, September, 1900, whole No. 15, pp. 458–480.

[b] Short sections of Berlin's elevated road are underground, but it has not been included in this article because so small a portion will be below the street level.

RAPID TRANSIT IN LONDON.

Owing to the enormous cost of constructing underground roads, a large daily traffic is essential to successful operation. This condition appeared first in London. When railroads were invented and their utility generally recognized, London was already a city of considerable size (population in 1851, 2,363,274). Its ancient streets were considered too sacred to be polluted by a noisy monster, and the importance of rapid communication between the central portion of the city and suburban areas was not yet recognized. Thus the first steam railroads were halted at the threshold of the inner city and made to build their terminal stations some distance from the center of commercial activity. With the growth of the city and the giving over of certain portions almost exclusively to business, some means of communication between the various depots became necessary. Steam surface roads were out of the question; electricity and cable traction had not been invented, and horse cars were too slow. Underground steam roads seemed the only alternative.

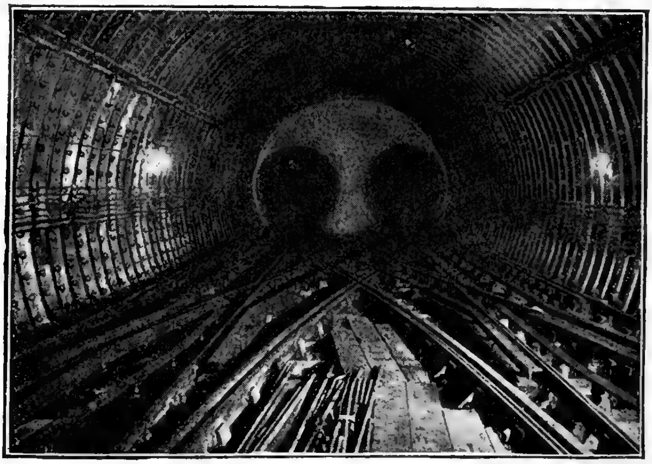

Fig. 1.—The Central London tunnel.

For years the construction of these lines went on, until at present there are 300 miles and upward of 270 stations within a 6-mile radius of Charing Cross. These railways probably carry over 300,000,000 passengers annually, and, including the omnibus, tramway, cab, and steamer passengers, the total approaches very nearly to 1,000,000,000 persons annually.

The unpleasant features of travel in the "underground"—the dingy entrances, the dark tunnels, the dirty, crowded, and dimly lighted cars, the sulphurous fumes from the engines, the dirt-laden air—were appreciated from the start and grew worse as the traffic increased. The lines were mostly near the surface, and openings were provided at short intervals to permit the smoke, steam, and

gas to escape, but they very inadequately performed that function. The managers, with the characteristic English slowness to adopt new methods and the desire to make large profits, reminding one of the New York Manhattan Elevated Railroad Company, refused to adopt electric traction, and until 1890 there was no method of rapid transportation in London other than the steam roads.

In that year the City and South London Electric Railway was opened, about 3½ miles in extent, extending from near the monument, in King William street, only a few blocks from the commercial center of the metropolis, to the suburban district of Stockwell, upon the south side of the Thames. The success of this road and the desire for access to the heart of the city led the Southwestern Railway—one of the most important English roads—to construct a short electric line between its Waterloo station and the Mansion House, opposite the Bank of England. This line is very short, only 1½ miles in length, but it does assist in solving the problem of urban transportation in that it brings the suburban districts reached by the Southwestern into closer communication with the business portion of the city.

The Central London Railroad, the latest, largest, and best equipped of all London subways, most nearly resembles, from the point of location, the New York subway. It runs from the Bank of England, under Cheapside, Newgate, Holborn Viaduct, and Oxford street, past St. Paul's Cathedral, Hyde Park, and Kensington Gardens to a station in the suburban district of Shepherd's Bush, a total distance of 6½ miles. There is a large traffic toward the Bank of England in the morning and to the West End in the evening, and the only means of transportation until lately was by omnibus or carriage or a roundabout route via the underground. No tramway has been permitted to occupy this main artery, and the new underground road will greatly add to the transportation facilities of London.

Various other electric underground lines have been proposed, and within the near future the Metropolitan and the Metropolitan District railways, now operated by steam, will adopt electricity as a motive power. Bids and plans have already been called for.

CONDITIONS IN BUDAPEST.

After London, Budapest was the first city to build a subway. Here it was the outcome of various plans for joining the central and business portion of the city with the park, a favorite rendezvous some 2½ miles distant. Nothing definite was proposed until the spacious and handsome Andrassystrasse was laid out, which offered a direct and attractive route for a street railway. Application was made for permission to build a horse-car line, but the plan met with strong

opposition chiefly upon æsthetic grounds. Several years later, after a short experimental electric line had proved a success, the scheme was again resurrected, electricity being the motive power. This proposal met a fate similar to its predecessors and led to the construction of the subway. In 1894 the concession was granted, and two years later the line was opened to the public. No other project is at present being considered; the transportation problem is not so serious as elsewhere, and the tramway system is very efficient, giving satisfactory service.

THE GLASGOW SUBWAY.

The Glasgow subway was started several years before that in Budapest, but being much larger in scope and more difficult to construct, owing to the great amount of tunneling necessary, it was not opened until the latter part of 1896. Even then it did not remain open, for the traffic was so much heavier than anticipated that it was necessary to close the line for a few weeks and improve the facilities for handling crowds.

The first definite project for an underground road culminated in 1887, when a bill was introduced into Parliament to authorize such an undertaking. The local authorities opposed it, because they feared that tunnels under the Clyde would render any further deepening of the river impossible and thus seriously interfere with the commercial development of the city. However, in 1890, a bill was passed; these objections did not seem of sufficient importance to counterbalance the need for rapid transit. Short sections of the steam roads, similar to those in London, had been operated for some time below the surface, but they reached only a few suburban districts. The new subway connects the business portions of the city with the residential areas to the west and northwest. Its eastern extremity is in the heart of the city, from whence the line makes a broad swing to the west, some 7 miles in circumference.

As yet there seems to be no competition between the subway and the municipal street railways. The latter do not reach many of the suburbs served by the subway, and the long-distance traffic does not use the surface lines because they are slower. Even with the proposed extensions, there will be abundant traffic for each system.

BOSTON'S SUBWAYS.

The Boston subway was opened in 1898. It is entirely unlike every other line, not being a separate and distinct system, but merely affording to the surface lines a means of reaching the business districts without using the surface of the streets. Prior to its construction the street car lines from the many suburban districts around Boston all met on Huntington avenue, Tremont and Boylston streets, or at Scollay square. Between Scollay square and the junc-

tion of Tremont and Boylston streets the congestion was so great that traffic was almost wholly impeded during the busiest hours of the day. Various solutions of the problem were proposed from time to time. An elevated road was rejected by a popular vote, and the proposed widening of the streets involved so great an expense as to be impracticable. The only comprehensive scheme seemed to be a subway in the congested district, and in 1894 an act was passed authorizing its construction. The results have been most satisfactory. The streets are not nearly so crowded as before, and there is a great saving to the passengers of the time necessary to reach the central portion of the city from almost any suburb. The total length of the subway is $1\frac{2}{3}$ miles, and contains over 5 miles of track. Several additional lines are under consideration.

THE COMPREHENSIVE SCHEME FOR PARIS.

The problem of rapid transit was first agitated in Paris almost half a century ago, and as early as 1870 the municipal authorities began seriously to study various solutions. In imitation of other

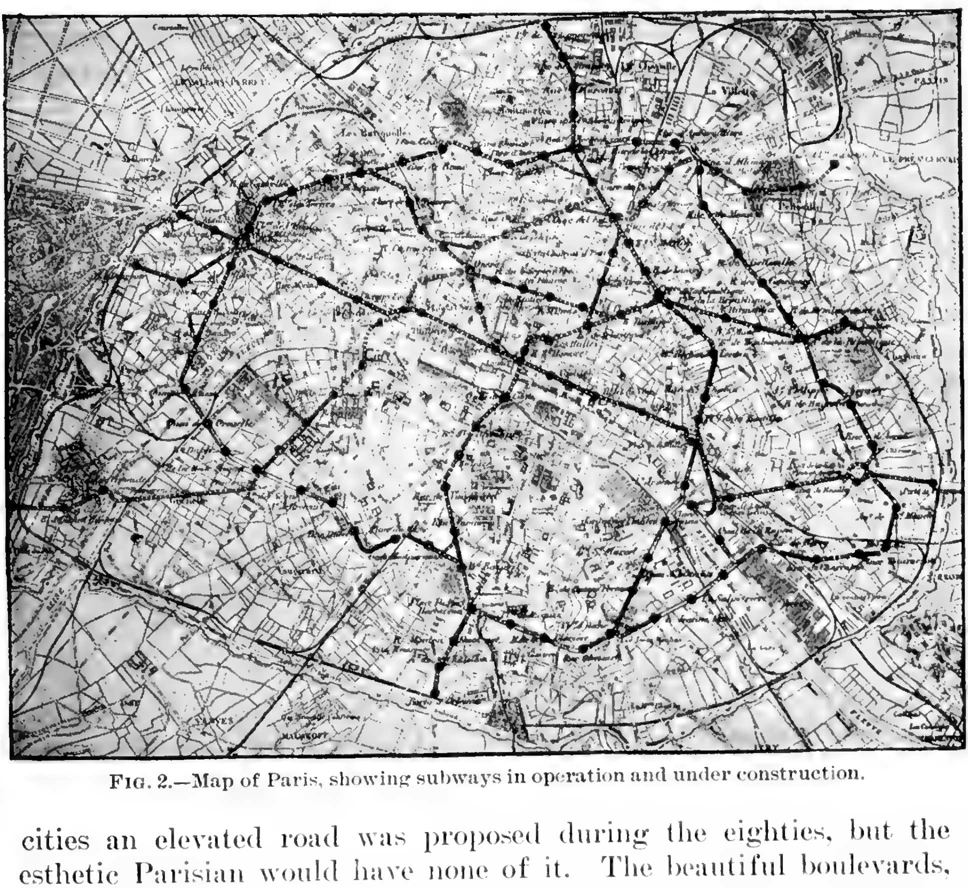

FIG. 2.—Map of Paris, showing subways in operation and under construction.

cities an elevated road was proposed during the eighties, but the esthetic Parisian would have none of it. The beautiful boulevards, streets, and public places, laid out by Baron Haussman at great

expense, must be preserved at every cost. And true to French custom no plan would be approved until a comprehensive scheme for the whole city was formulated. This had been accomplished by 1896, an electric subway having been decided upon. The street traffic had become so congested that no more surface lines or omnibus routes could be added.

The extent of the Paris metropolitan subway is indicated by the above map. When it is entirely completed the system will be nearly 40½ miles in length, will cost the city $36,000,000, and the operating company about $10,000,000 more for equipment.[a] At present, only one section and parts of two others have been completely constructed and put in operation, namely, the line running from the Vincennes gate in the east, past the Hotel de Ville, the Louvre, and the Tuileries, down the Champs Elysees to the Place de l'Etoile, from which three lines operate—one to the Trocadero, one to Porte Dauphine, and one to Porte Maillot. The total length is some 8 miles, and the cost about $7,000,000 for construction alone.

PUBLIC CONTROL IN GREAT BRITAIN.

The relation of the municipality to the subways varies greatly from city to city. In no instance have the city authorities undertaken operation, but in Paris and Boston, as in New York, the public owns the subway, having constructed it at public expense.

The extent of public control is least in Great Britain, there being a marked difference between street railways—surface lines—and underground roads. The former are subject to strict control, and the municipality may take over a line twenty-one years from the time when the franchise is granted, or may construct or purchase the tracks and rent them to a private company. But no underground road is municipally owned or operated, and no public authority has the right under the act granting the franchise to purchase a line. Of course the local authorities may regulate to a moderate degree, but beyond a somewhat restricted exercise of the police powers they may not go. The most important provision found in any of the acts, except clauses protecting avowedly private interests, such as are to be found in acts creating steam railroads using private property principally,[b] is one requiring workmen's trains to be run each day, morn-

[a] The city has planned for two more sections, making eight in all, bringing the total length up to 48.5 miles, and the cost up to between $45,000,000 and $50,000,000. These last two sections have not yet been authorized by the central government.

[b] The restrictions imposed upon private companies relate principally to the amount of capital that may be issued, the extent to which loans may be negotiated, location of the road, the property purchased, the indemnities paid, the maximum fares charged, the number of trains run, the motive power used, etc.

ing and evening, at a fare not to exceed 2 cents for the whole or any part of the journey on the Central London Railway. Of course Parliament knows no higher law than its own will, and may impose any restrictions or may order compulsory purchase at any price, but all such proceedings are without the realm of probability.

This difference between underground and tramway lines rather surprises one at first, for British cities have gone as far in the direction of municipal socialism as those of almost any other country. The explanation is a very important fact, viz, that municipalization in Great Britain is not so much an economic movement as the expression of the desire that the local governments keep control of the streets. The underground roads, in so far as they cross or pass under the streets and public places, are using public property, to which the

FIG. 3.—A station on the Central London Railway.

public authorities have as clear a title as that of a private individual to the ground under his house. The law knows no limit either above or below the surface. Yet no demand has been made upon the underground lines for payment or for the reservation of the right to take over the line. It is to be borne in mind, however, that the underground roads, especially those constructed since the movement for municipalization became strong, are some distance below the surface,[a] that their construction and operation necessitates very little disturbance of the street surface, and that instead of increasing the street traffic they relieve it. Further, they do not promise to be exceedingly remunerative, and without public aid either through subsidies or free grants to use the ground below the surface of the streets many of

[a] The average depth of the Glasgow subway is 29 feet, and the Central London Railway is everywhere, except at the western terminus, which is on private property, at least 30 feet below the surface of the streets. Only the Metropolitan and the Metropolitan District Company are near the surface and have open subways. These are the steam roads, which got their powers years ago.

them would not have been built. Both London and Glasgow have recognized these facts, and have not opposed the companies when they have appealed to Parliament for power to use the ground below the streets.

FRANCHISE IN BUDAPEST.

The nearest approach to British conditions is to be found in Budapest. There the city has invested nothing; the subway has been built, equipped, and operated by a private company. But the city has reserved the privilege of taking over the line in 1940, when the concessions for the surface lines expire, provided announcement is made of its intention two years previous. Otherwise the franchise runs ninety years from 1896, or until 1986. The maximum fare is fixed at 10 kreutzers (5 cents) during the first fifteen years, after which the city authorities may require a reduction. The city will receive from the gross revenues an amount to be calculated on the following scale:

	Per cent.
During the first ten years following a period of twenty years, 1916–1926	1
During the second ten years following a period of twenty years, 1926–1936	2
During the third ten years following a period of twenty years, 1936–1946	3
During the fourth ten years following a period of twenty years, 1946–1956	4
From this time to the end of the concession, 1956–1986	5

During the first twenty-five years the city can not grant any other concession for the establishment of a system of transportation of any kind between the center of the city and the park. And for the first fifteen years the company is exempt from taxation. The city, of course, possesses in addition the usual police powers, and the concession contains many provisions specifying how the subway was to be built and how it is to be operated.

TERMS OF THE PARIS CONCESSION.

The position of the Paris subway is the result of many compromises between the municipal council and the central government whose approval was necessary for the execution of the project. The central authorities insisted that the subway be connected with the railroads in order that trains from the country might be run right through to the center of the city and a suburban traffic thus developed. The municipality feared that the railroad companies would get control of the subway and that a large portion of the population would be induced to leave the city and live in the suburbs, thereby decreasing the city's revenue from octroi. A compromise was finally effected, and in the early part of 1898 the act was passed, which fixed the gauge of the road, over which there had been so much dispute, at the standard width. But the city, in order to prevent the railroads from ever sending their cars over the subway, has built

the tunnels so narrow that only those cars can be used that are especially constructed for the subway.

Another point upon which the municipal council and the central government did not agree was as to who should operate the lines. The council wished not only to own but to operate the road. The central authorities objected, but finally compromised upon municipal ownership and private operation. This plan offers many advantages. According to a general law passed in 1842, a private company gets a franchise for seventy-five years if it builds a railroad; but if a public authority constructs a line it may shorten the period to thirty-five years. Further, under private ownership, a company would find considerable difficulty in raising sufficient capital to build and operate the whole system. Paris could borrow the money easily, and not only easily, but at a lower rate of interest than a private company. This saving would be no small factor and will enable the road to lower fares ultimately.

The contract between the municipality and the operating company is most interesting. The franchise runs for thirty-five years, but at any time within seven years from date of construction the city may acquire the lines. The company agrees to maintain the highest degree of efficiency, to give to its employees an annual vacation of ten days with full salary, to give them full pay during military instruction and sickness, to insure them against accident, and to pay the city 2 cents for every first-class ticket and 1 cent for every second-class ticket sold, with the added provision that when the annual passenger traffic exceeds 140,000,000 persons, this sum shall be increased, reaching at the highest mark 2.1 cents for each first-class and 1.1 cents for each second-class ticket. As the concession fixes the rate for a first-class ticket at 5 cents and for a second-class ticket at 3 cents, and for school children with teacher at a uniform rate of 1 cent, about one-third of the entire receipts will go to the municipality and two-thirds to the company. As the cost will be about $35,000,000 for the lines thus far authorized, an annual revenue of $1,100,000 will be necessary to pay the interest, sinking-fund charges, and incidental expenses; operating expenses are paid by the company leasing the subway. Thus, if the entire system should carry only 125,000,000 passengers annually, the city would more than pay all expenses. As this is considered a very low estimate and as it seems almost certain that the traffic will far exceed this number, the city will probably find the subway a paying investment. The roads in London, Berlin, and New York carry nearly 5,000,000 passengers per mile per year; the Paris subway ought easily to reach the necessary 3,000,000 per mile per year.

The entire system of subways is not to be constructed at once, but is to be divided into six sections (two more have not been approved by

the central government), which are to be opened from time to time as specified in the act, until by 1916 every line will be in operation. All are to be operated by the present leasing company and upon the same terms as given above. The thirty-five-year period—the duration of the franchise—is to run from the date of opening each line, and to prevent any inconvenience which might arise from franchises for different sections falling in at different dates, the concession provides that the company may retain possession of all until the termination of the last franchise, and shall pay 45,000 francs per kilometer per year ($14,000 per mile) for every line whose lease expires previous to that time.

CONDITIONS IN BOSTON LEASE.

Like Paris, Boston owns its subway and has rented it for twenty years to a private company—the West End Elevated Railway Company, which has subleased it to the Boston Elevated Railway Company. The rental will never be less than $4\frac{7}{8}$ per cent of the cost of the subway, and if this sum does not amount to 5 cents for each car using the subway, it shall be made up to this sum. The income will pay the interest on all outstanding bonds and provide a sinking fund to extinguish them at maturity—forty years hence. All operating expenses are paid by the operating company, and at the expiration of the lease the city will pay the fair value of all rails, pipes, wires, etc., which are affixed to the subway.

COMPENSATION.

Comparing the various methods of securing compensation, it is evident that in no instance have large profits been secured. Budapest undoubtedly receives the most, considering the fact that it has invested nothing, for even the expense of rearranging sewers, water mains, conduits, etc., was borne by the subway company. Paris may make the most, for if the traffic greatly exceeds 125,000,000 persons annually, the net profit will be more than 5 per cent of the gross receipts, as the rate is about 33 per cent of the gross receipts. However, if the traffic should fall considerably below this figure, the municipality will need to make up the deficit from other sources. There seems to be little risk in this direction, and Paris has followed its usual course of exacting large payments from municipal monopolies rather than of requiring lower prices and increasingly better service. London and Glasgow are at the other extreme, and New York and Boston are not far distant, for the payments are not large, barely exceeding for the present the interest on bonds issued for the construction of the subways and sinking fund charges to wipe out the debt.

Considerable variety exists also as to the basis for compensation. Budapest uses gross receipts—an easily ascertainable basis and freed

from much adverse criticism by the requirement that the rate increase as the years pass, or, in other words, as the road becomes more remunerative. Paris has adopted an even simpler basis, receiving a certain fixed sum for each ticket sold. An attempt has also been made to vary the amount with the traffic, but not quite so successfully as in Budapest. In Boston and New York the cost of construction is used as a basis, and the payment to the city is a fixed sum, no matter what the profit or the loss to the private company or the size of the traffic.

MOTIVE POWERS.

An examination of the roads themselves reveals a great difference between those recently constructed and the underground lines in London built many years ago. Steam as a motive power has given way to electricity. Every London line constructed since 1890—the date when the City and South London road was opened—has adopted the third-rail electric system, as have also Paris and New York. The Budapest and Boston subways use the overhead trolley. Glasgow clings to cable traction, which is largely accounted for by the conservatism of the Scotch and the fact that in 1890, when the work was begun on the subway, electricity had not yet clearly demonstrated its efficiency. Cable traction was much cheaper, and upon the steep grades the car going down will help to pull up the car going in the opposite direction. The act of Parliament imposes no conditions except that steam can not be used. The Glasgow subway is unique, in that it is the only underground cable railway for passengers in the world. Thus far it has worked very well.

TRAVEL A PLEASURE.

All the modern subways, even that of Glasgow, have adopted electric lighting, and the cars and tunnels are in marked contrast to those of the steam lines in London, which are dimly lighted, dirty, and forbidding. Glazed tiles have generally been used, especially at the stations, and in every way the comfort and pleasure of the passengers have been administered to. The entrances in Boston and Budapest particularly are very artistic, and instead of being repellant, because of their dirt and ugliness, even add to the beauty of the streets and public places in which they are located. The London electric lines, being situated many feet below the level of the streets, have provided spacious elevators, which counteract the disadvantages of deep-level travel. The Paris, Budapest, and Boston subways do not need them, being located near the surface of the streets. The Glasgow company has one, in Kelvinbridge, where the road is 115 feet below the crest of the hill, and New York will have a few where the road is far below the surface.

In the construction of the subways, plans much the same have been followed everywhere. Where the road level is near the street level, an open ditch was made, steel framework inserted, and the street pavement replaced. Where this was impracticable, tunnels were driven; and in a few instances short viaducts were erected. The Budapest subway is everywhere just below the street level, and consists of two parallel lines at the same level, separated only by steel pillars, station platforms, or thin walls. The Paris subway likewise consists of two parallel lines and always at the same level, except where one section crosses another and a dip is made to avoid crossing at grade. Some of the distance the lines run side by side in a single tunnel; in other portions each line has a separate tunnel, uniting only at stations. The Glasgow road consists of two distinct tunnels throughout, except at stations, as is true of nearly all the London electric lines except the Waterloo and City road, which has only one line almost all the way. The Boston subway has from two to four lines, usually at the same

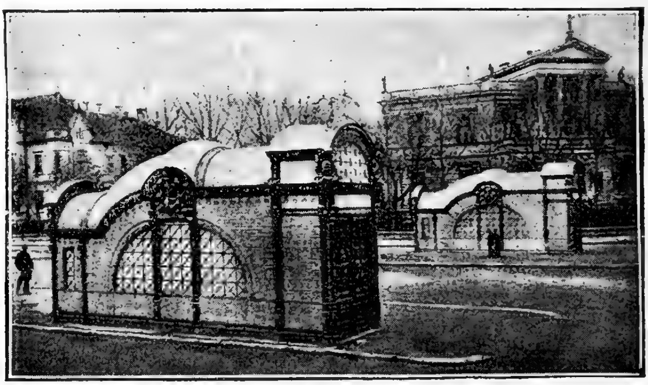

FIG. 4.—Budapest stations.

level, except where it is necessary to raise or lower one to avoid grade crossings. The New York line is the only one that has tracks for the special purpose of running express trains; and with the Central London road is unique in raising its stations above the level of the road. Each train on its departure thus is accelerated by the force of gravity, and as it approaches is checked by the same force. This will greatly increase the rate of speed by reducing the time required for stopping and starting.

Most of the modern subways are adopting the American style of car, with an entrance at each end, in place of the old-style compartment coach. Even the London roads are making the change, and the Glasgow line introduced them at the start. The Paris car is a hybrid, having two doors on each side, one set being used for entrance and the other for exit. The train idea seems also to be spreading, as being more economical and better adapted to handling large crowds.

There is one marked difference between foreign and American lines. Most of the former have first and second-class compartments or cars; the latter charge the same fare for every one. The Glasgow subway maintains only one service and the tendency elsewhere is in this direction. Some London roads have already made the change.

The uniform fare, regardless of distance, is also more common with us than abroad. In Paris and Budapest it is in vogue, but the lines are so short as to render a graded system unnecessary. The Glasgow company intended to adopt it, but as the cars run continuously around the circle, one would be able to ride indefinitely for one fare. To prevent this, a zone system was adopted. A penny ticket (2 cents) allows one to go as far as the fourth station from where he enters the car, or about 1½ miles—one-fourth the circumference

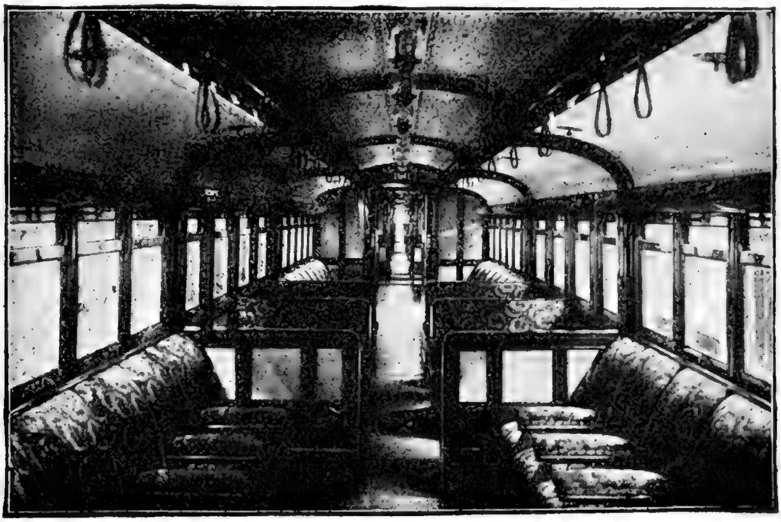

Fig. 5.—A Central London Railway car.

of the road. A 2-penny ticket (4 cents) entitles one to travel any distance, but not more than once around the circle. A ticket is given each passenger, which he gives up upon leaving the station at his destination. Any one who has ridden farther than his ticket indicates is thus found out and required to pay.

That the subways of London, Paris, Budapest, Glasgow, and Boston were needed and are performing a useful social service is shown by the large number of passengers carried. Their influence can only partially be estimated, but undoubtedly the effect upon social conditions, especially housing and overcrowding, is considerable, not to mention the saving of time in going to and from work. Doubtless rapid transit will not solve either the housing problem or transform our cities into Utopias, but it will alleviate social conditions and prevent what otherwise would be unbearable evils.

SIR GEORGE GABRIEL STOKES.

GEORGE GABRIEL STOKES.[a]

By Ernest W. Brown.

George Gabriel Stokes was born in Ireland on August 13, 1819. His father, the Rev. Gabriel Stokes, was rector of the church in the little village of Skreen, Sligo County, his mother being a daughter of the rector of Kilrea. He was sent for his early education to Walls's school in Dublin, and afterwards to the college in Bristol, whence, in 1837, he proceeded to Cambridge, entering at Pembroke College. His life was henceforth fully identified with the interests of his college. He was elected to a fellowship just after taking his degree in 1841, and retained it until his marriage in 1857 to a daughter of the Rev. T. R. Robinson, D. D., director of Armagh Observatory. Under the statutes of the university at that time in force, this event compelled him to vacate his fellowship, but he was reelected in 1869 under the new statutes and only resigned in 1902, when he was 83 years old, to become master of the college. His tenure of the latter post was short; he died on February 1, 1903.

Practically the whole of Stokes's scientific life was connected with the interests of two bodies—his university and the Royal Society. He graduated as senior wrangler in 1841, the first of the great triumvirate which attained the coveted honor in three successive years—Stokes, Cayley, and Adams. There were giants in those days. Sylvester and George Green had taken their degrees in 1837, and Lord Kelvin followed in 1845, and chief among those of note in other lines was Charles Kingsley, who took honors in mathematics and classics in 1842. This period was in reality not far removed from the time when British mathematics had been entirely isolated. Until the beginning of the century Newton's methods and fluxional notation were almost exclusively employed, and it was only some ten years before Stokes matriculated that the influence of Woodhouse, aided later by Peacock, J. F. W. Herschel, Babbage, Whewell, Airy, and others, was successful in completely establishing continental methods for examination purposes and in forcing the recognition of the mathematical work

[a] Reprinted by permission from The Physical Review, Lancaster, Pa., Vol XVIII, No. 1, January, 1904.

which had made such advances outside the country. Thus the men of the period, in the middle of which came Stokes, had the advantage of being trained by those who were thoroughly grounded in the old methods, but who had spent time and energy in working up and introducing the new. Neither was the intellectual activity of the pioneers of the new movement confined to research in mathematics. Text-books had been written setting forth the continental methods, and translations of foreign works had been made. A classical tripos had been established in 1824, but all candidates who went in for it were required to have taken honors previously in mathematics—a rule abolished in 1850.

The mathematical power of Stokes began to show itself immediately. His first paper was published the year after he took his degree and the decade which followed was certainly the most fruitful of his life in regard to the equality and quantity of the work which has come directly from his pen. The Royal Society Catalogue contains the titles of over 50 papers printed within this period, and many of these are not only of far-reaching importance but mark the beginnings of his researches into almost every department of mathematical physics—hydrodynamics, light, elastic solids, the mathematical expression of wave motion by Fourier's series, sound and conduction of heat. Modest as he was concerning his own achievements, he thought nearly all of these papers sufficiently good to be included in his collected works, the first three volumes of which cover this period alone. To mention a few of the most important, we have the researches On the Steady Motion of Incompressible Fluids and On the Theories of the Internal Friction of Fluids in Motion, and of the Equilibrium and Motion of Elastic Solids, with a Supplement, which together constitute the complete foundation of the hydrokinetics of the present day. In the paper On the Effect of the Internal Friction of Fluids on the Motion of Pendulums, he considers and works out the effect of viscosity on various kinds of motion. Deep-sea waves and the solitary waves are very fully treated in the memoir On the Theory of Oscillatory Waves. But the theory of light was the subject in which he seems to have been most willing to work. The two papers, On the Dynamical Theory of Diffraction and On the Change of Refrangibility of Light, in the latter of which fluorescence is described and explained, would have alone sufficed to make his reputation.

Two further papers, On the Critical Values of the Sums of Periodic Series and On the Numerical Calculation of a Class of Definite Integrals and Infinite Series, must be mentioned, not only because of their great intrinsic value, but also because they show that the author was right abreast of the developments in pure mathematics at that time and that he was able to advance them and use them as an instrument of research for the investigation of physical problems.

This last fact is perhaps worth insisting on at the present time, when the separation between pure mathematics and physics has become far wider than is advantageous for either. The physicist works mainly in his laboratory, the mathematician at his desk, neither intrenching on the domain of the other. Even the magnificent work of Poincaré, introducing the rigorous and fruitful methods of pure mathematics for the treatment of physical problems, is only a partial step in the right direction. With Stokes this divorce never occurred; experiment went hand in hand with theory. As early as 1840 he had fitted up a small laboratory in his rooms, of simple character it is true, but none the less sufficient to test, sometimes searchingly, the results of his theories. And it was the same all through his life. He was never content to leave a theory unconfirmed by experiment, and if a new observation were made it must be compared with theory. These qualities are especially noticeable in some of his earlier papers. In that on internal friction, he explains the suspension of clouds and the subsidence of ripples and waves after a storm: in those on oscillatory wave motion, the well-known experiments of Scott Russell are fully considered; his paper on diffraction is divided into two parts, consisting of his theory and of the experiments which he made to test it, and so on. Later in life he would, in a short note or a few remarks, give the main outline of an explanation of some new phenomenon; further research by others usually proved him to be correct.

This active period quickly brought recognition to him. In 1849 he succeeded to the Lucasian chair of mathematics in Cambridge, a post held previously by Isaac Barrow, Newton, Woodhouse, Airy, and Babbage, and five years later he was elected secretary to the Royal Society. He was not content with delivering the two courses of lectures required of the professor by the regulations. He let it be known that he considered it part of his duty to help students in their work, and such help from a man like Stokes was not to be despised. He was always ready to give assistance, whether it was asked for work already started, or in suggesting new problems to be undertaken, or in giving encouragement where failure seemed likely. This trait was even more conspicuous during his thirty-one years' tenure of the Royal Society position. Naturally brought into contact with all the best work which was being done throughout the country, he largely gave himself up to helping others. This was undoubtedly the main reason for the smaller output after this time. As against 50 papers produced up to 1852, we find only 56 from then until the end of 1883, and many of the latter consist of addresses and short notes on such subjects as chemistry, details of instruments, and history of science, all valuable but perhaps not epoch-making like the earlier memoirs. His reward was the frequent acknowledgment of his assistance which those alone who had received knew how to appre-

ciate. A generous tribute is given by Lord Kelvin[a] of his own indebtedness, and a further one by an anonymous writer,[b] who tells that though he was previously quite unknown, some work of his attracted the attention of Stokes and a correspondence was started in the course of which on one particular day he received as many as three letters and a telegram! It is unnecessary to say a word on the quality of the assistance given. It was the same throughout; knowledge and time were always at the disposal of small and great.

It has been said that much of Stoke's work was given to others, and indeed some of it was never published in scientific journals at all. An instance of this occurs with reference to the transformation of a line integral into a surface integral which he put as a question in a Smith's prize examination paper in 1854. Again, he had thought out the physical basis of the solar spectrum some seven years before Kirchhoff, and had been in the habit of lecturing on it. Stokes deprecated any attempt to obtain for himself the credit of this discovery, saying that he had failed to take an essential step in the process. It is possible that the papers he left behind will tell even more of his own work than we know now, and they will doubtless add much to the scientific history of the second half of the last century.

Amongst other honors, Stokes received the Rumford medal in 1852, the Copley medal in 1893, was Burnett lecturer 1883–1885, Gifford lecturer 1890–1892, and was created a baronet in 1889 when Lord Salisbury was prime minister.

In 1855 Stokes received the highest scientific honor which England land has to bestow—the presidency of the Royal Society; this he held until 1890. From 1887–1891 he represented the University in Parliament. Being still Lucasian professor, he thus attained the unique distinction of holding the three positions simultaneously. Only once before had one man, Isaac Newton, occupied them all, and in his case the tenures were at different periods of his life. In 1899 Cambridge University fittingly celebrated the jubilee of his election as professor, inviting representatives from all parts of the world and publishing a memorial volume of the Transactions of the Cambridge Philosophical Society—a body to which many of his papers had been communicated. Although at this time about to enter his eighty-first year, he seemed able to endure fatigue without showing signs of his advanced age. On the chief day set apart by the university he attended morning and afternoon congregations of the senate, a lunch, and a late banquet, and the following day was early in London to attend a committee, only closing his labors on various matters late that night.

A word must be said concerning Stokes's relation to religious questions, partly because they evidently entered much into his thoughts

[a] Nature, February 12, 1903. [b] Ibid., February 19, 1903.

and formed an essential part of his character, and partly because during the last twenty years of his life there were published addresses and papers on the question by him. On several occasions he spoke before the Church Congress, the Victoria Institute, and other bodies on the relation between science and faith. What value is to be set on these, this is not the place to discuss; it is sufficient to mention that he took a prominent part in the efforts made in England in educating the public to higher views of the relations of science to theology, and in rescuing the study of the former from the doubtful position which it had, even among some of the more advanced students of religious questions. His own personality and the methods of treatment which he adopted were always on the side of promoting good feeling and tending toward the prevention of acrimonious discussion amongst those whose opinions differed most widely. He avoided, as a rule, dogmatic statements and treated the questions in his usual scientific manner, allowing his own opinions to be inferred rather than expressly stated.

The published portraits of Stokes, representing him with a somewhat severe type of countenance, fail to bring out a characteristic expression. Ordinarily silent in society, he would freely talk on any subject that interested him. While telling of some remarkable fact or observation, the broad high forehead would pucker into a thousand wrinkles and a smile would light up his face with a brilliancy which seemed to show a concentrated picture of the whole man. Those who had the privilege of listening to his highly finished and carefully worded lectures on the wave theory of light delivered without a note, or of watching the simple experiments and diagrams with which he illustrated them, will remember how eagerly they looked for the first symptoms of this change. The lectures, too, were characteristic. Toward the end of the course, evidently wishing to give more than was possible in the limited time, he would continue further and further over the allotted hour until the last day when, on one occasion, amid the gradual disappearance of the class to fulfill other engagements, he kept those who remained interested for nearly three hours.

There was but little apparent failure of Stokes's physical and intellectual powers until within a few days of his death at the age of 83. He died as he had lived, in harness, and a great figure passed away from the scene at the close of a well rounded and successful career. His work, mainly on wave motion and the transformations which, in its different forms, it undergoes under various circumstances, has already taken a permanent place in the history of science. And he has left behind with those who knew him a memorial of himself which will not be easily effaced.


Dr. Karl von Zittel

KARL ALFRED VON ZITTEL.

Translated by CHARLES SCHUCHERT.[a]

During an excursion in southern Tyrol in the summer of 1898, Privy Counsellor Karl Alfred von Zittel, professor of geology and paleontology at the University of Munich, Germany, first began to suffer from heart trouble. On the evening of the 5th of January, 1904, he died, being then in his sixty-fourth year. In Zittel, the Bavarian Academy of Sciences has lost its president, the University of Munich one of its greatest teachers, and paleontology its master. For thirty-five years he conducted the periodical Palæontographica, and was about to complete the fiftieth volume of this great paleontological serial, and to celebrate the event with words of rejoicing and warranted pride, when his death changed contemplated joy into deepest mourning.

Karl Alfred von Zittel was born on the 25th of September, 1839, in the parsonage at Bahlingen, the seat of the rulers of Baden. He was the youngest son of Pastor, later Dean, Karl Zittel, who was prominent in the political life of Baden and leader of Protestant liberalism.

Young Zittel showed an early love for natural history, and when his father removed to Heidelberg, he, as a student in the gymnasium, spent his spare hours in the well-known mineral shop owned by Lommel. Here he arranged and identified fossil snails and shells, and thus laid the foundation of his surprising and accurate knowledge of forms—a knowledge which, combined with a brilliant memory, later distinguished him as master in paleontology.

In 1857 he entered Heidelberg University as a student of the natural sciences, especially of paleontology. At that time it was neither comfortable nor profitable to study paleontology at Heidelberg, because of the almost insurmountable difficulties in securing the three students necessary to induce Heinrich Georg Bronn, author of Lethæa Geognostica and of Index Paleontologicus, and joint pub-

[a] A free translation, greatly condensed, of the German memorial, Karl Alfred von Zittel, Ein Nachruff, by Prof. J. F. Pomepckj, published in Palæontographica, Band 50, 1904, pp. 3–28. Extracts from the writings of Suess, Osborn, and Woodward have also been added.

lisher with C. Leonhard of Neues Jahrbuch für Mineralogie, to give a course in that science. But once during Zittel's term of study were the three students secured.

Doctor Zittel continued his studies during the year 1860 at Paris. Here he met the venerable Elie de Beaumont, who, with Dufrénoy, worked for eighteen years on the first geological map of France. Of him Zittel said, "The geological fame of Elie de Beaumont rests on his admirable field work and his writings concerning the age and origin of mountain systems." Around Beaumont and Edmond Hébert, the honored teacher at the Sorbonne, and de Verneuil, there gathered many of the geologists of France—Eudes Deslongchamps, Albert Gaudry, Nunier-Chalmas, and others. All these became the friends of the young German, and remained so. As Zittel especially cherished this attachment, they rewarded his loyalty with their loyalty. As proof of their high estimation of him he was elected in 1898 vice-president of the Geological Society of France, a distinction rarely bestowed on a foreigner.

In 1861 he studied at Vienna, then especially noted for geology and paleontology. There he met Wilhelm von Haidinger, the founder of natural history in Austria, and at that time the head of his creation, the k. k. geologische Reichsanstalt. Of this remarkable man Suess has written, "He was not a charming speaker. However, if a young man had the courage to seek him at his home in Ungargasse, he would then unbend his dignity. With both hands he would hold his guest during the entire visit, while his silvery locks of hair streamed down over the rosy cheeks preserved into old age. With many a 'ja, ja, ja,' he would endeavor to stimulate and attract and attach to himself the young mind, as if he wished to pour into it some of his own warmth and an exalted conception of the duties and the life objects of the naturalist. At the same time he would seek to indelibly impress upon the listener how much there is to work for in this beautiful world, and how much can be accomplished by united effort." Associated with Haidinger at that time at the Natural History Institute of Vienna were Franz von Hauer, the geologist par excellence of Austria, Dionys Stur, Johann Cezjžek, Fötterle, Guido Stache, and many others. The young, genial Eduard Suess had then just begun his highly honored career as the first professor of geology at the University of Vienna. At the Royal Mineral Cabinet, Zittel met the distinguished Moritz Hörnes, famous for his wide knowledge of Tertiary fossils—a knowledge young Zittel must have greatly valued because of his own previous training in the classic Tertiary basin of Paris. At the Technical High School there taught Ferdinand von Hochstetter, a student of Quenstedt's, and there also lived at Vienna the Huguenot, Ami Boué, a great traveler, of profound learning but singular in person.

In 1862 Zittel was a volunteer assistant to the geological survey of Austria, being associated with F. von Hauer and G. Stache in mapping the coast region of Dalmatia.

In 1863 he was offered the position of professor ordinarius at Lemberg, but declined it to accept a far less well-endowed position as assistant in the Royal Mineral Cabinet of Vienna, now known as the Royal Natural History Museum. This determination on the part of the idealist, Zittel, caused much surprise, yet to him the great paleontologic collections of Vienna were of far greater interest than the salary attached to the professorship. His decision was fortunate for paleontology; he here began his paleontologic career in his studies of the bivalves of the Gosau formation—his first extensive work.

In 1863 he returned to his home in Baden, and accepted the professorship of mineralogy, geognosy, and paleontology at the Polytechnic School at Karlsruhe. Here he remained three years, during which time he married Miss Ida Schirmer, a daughter of I. W. Schirmer, the landscape painter, and director of the Karlsruhe Art School.

At the age of 27 years, or in the autumn of 1866, he was called to Munich, to the distinguished position of professor of paleontology and conservator of the paleontological collections of Bavaria. This position had been made vacant by the early death of Albert Oppel. In 1880 he declined a call to Göttingen as successor to von Seebach, and was made professor of geology; also, after the death of Schafhäutle in 1890, he was appointed conservator of the Bavarian geological collections.

"Munich became Zittel's second home. Here he taught and labored for more than thirty-seven years. These were years replete with continuous and fruitful investigation and instruction—a long period of labor which was only occasionally interrupted by grudgingly allowed vacations and these were not infrequently devoted to scientific journeys. Strict and loyal in the fulfillment of duty, and an example to all as a lover of work, Zittel could be found day after day in his simple workroom in the grey Alte Akademie in Neuhauserstrasse. During his last months of illness it was very hard for him to be kept from the daily walk to his Institute and from the treasures of his collections. Ceaseless work was the motto of his life—even on his last sick bed he wrote for the completion of the second edition of his Grundzüge der Palaeontologie—till death put an end to his life and to his labors.

"At Munich Zittel entered the field of work to which he was eminently fitted. Here he was held in highest esteem, established a world-wide reputation, and created for himself and for Munich the greatest renown by his brilliant works, the chief being the Handbuch der Palaeontologie. The Munich Paleontologic Museum—Zittel's col-

lection—he made one of the greatest and most important scientifically of the world. At Munich he founded the most renowned chair, the largest school of paleontology, and quickly made evident the truth of the prediction of M. Hörnes in 1866, when Zittel was called to Munich: 'Through Zittel the leading position in paleontology, which heretofore Vienna has held, will be transferred to Munich.'

"Here Zittel was recognized without envy by the entire scientific world as the master of paleontology, the teacher of paleontologists."

A. S. Woodward has stated: "For more than thirty years he had been acknowledged as the leading exponent of the science which is intimately connected with the progress both of geology and biology. For a still longer period his charming personality had combined with his wide reputation to attract to the Palaeontological Museum at Munich students of the natural sciences from all civilized nations."

The master of modern paleontology passed away in Karl Alfred von Zittel. This was clearly shown during his life, and was also acknowledged in the numerous memorials which have been written of the great dead by Branco, Canavari, Dacqué, Diener, Günther, Hiegel, Jaekel, Kitchen, Osborn, Pompeckj, Rothpletz, and Woodward.

Zittel traveled extensively in the interests of geology; he made numerous trips to the Alps, went twice into Scandinavia, England, and North America, and more often to France and Italy, Russia and Algeria.

His first publications relate to minerals, mineral localities, and petrography. He next assisted in mapping the geology of Dalmatia, and then of Baden. In glacialogy he proved, in 1873, that during Diluvial time the glaciers extended across the folds of the Bavarian Alps far over the foreland of the upper Bavarian North Alps; and that to the work of glaciers is due the present topographic and orographic picture of the Bavarian high table-land.

In the winter of 1873–74 he was geologist on the Rohlfs expedition across the Libyan desert to the Siuah (Siwa) oasis. Of this then terra incognita he constructed a geologic map covering the region traveled, and showed by means of his abundant collections of fossils that the limestone plateau forming the base of the desert is of Eocene and Miocene age; further, that these are superposed on youngest Cretaceous or Upper Devonian, with a fauna indicating that this constituted a part of the Indian Cretaceous basin. The Sahara until then was believed to have been covered by the diluvial sea, and this fact lent itself to a ready explanation of the causes of the Glacial period in Europe. Zittel, however, exploded the myth of the Sahara sea by showing that during Diluvial time Sahara was land, and that the sand of the desert was not formed by the action of sea waves, but is due to weathering of the older sandstones.

In connection with his geologic work Zittel also became the historiographer of geology and paleontology. All that human mind and labor have produced since ancient times for the elucidation of the earth's history, all that the heroes, Werner, Leopold von Buch, Alexander von Humboldt, Hutton, Kant, La Place, Cuvier, Al. Brongniart, Lyell, Quenstedt, d'Orbigny, and the great number of more recent devotees have accomplished, all this Zittel had included in one brilliant picture in his Geschichte der Geologie und Palaeontologie bis Ende des 19ten Jahrhunderts. An English translation of this work was made in 1901 by one of his students, Mrs. Maria Ogilvie-Gordon.

Zittel's first paleontologic paper appeared in 1861, at a time when fossils had but one value—that for the determination of geologic age. The teachings of Cuvier then still held full sway, i. e., each fauna was a new creation and each disappeared through cataclysms. It is only since 1870 that paleontology has taken an active part in the establishment of the theory of evolution, and in reality it is only since that time that pure stratigraphic paleontologic studies have become more sharply distinguished from the biologic systematic, the latter more and more emphasizing the genealogic aspect.

From the end of the sixth decade Zittel's work begins to take on the character of paleozoology as contrasted with the older paleontology. By means of a study of the ammonites of the Stramberger beds, he is led to discuss the relationship of the forms, and is convinced that there are no unchangeable types, but that the species are simply isolated individual complexes derived from unbroken evolutional series. The cataclysm theory and the teachings of types being overcome, Zittel declares himself an evolutionist. He always remained so, and had a great influence on paleontology.

How the history of living organisms merges into the history of the earth is brilliantly described in Zittel's Aus der Urzeit, published in 1872 (second edition, 1875). Here he also discusses the hypothesis of the origin of the earth, following the teachings of Kant and Laplace, without, however, making dogmas of their theories.

In 1876 he began his classic studies on fossil sponges, determining their beautiful spicular structures by etching with hydrochloric acid and elucidating with the microscope. Until this time it was thought that the fossil sponges had little in common with recent forms, but Zittel showed that all can be grouped in the classification of living sponges are psendomorphs after siliceous forms, but that true calcareous sponges do exist among the fossils, a fact disputed by Haeckel. Zittel originated the classification of fossil and recent sponges, and actually made it possible to study fossil forms.

In the realm of vertebrate paleontology he has published several

papers, and "those on the Chelonia and pterodactyls from the lithographic stone of Bavaria are especially valuable contributions to science" (A. S. Woodward).

Zittel's great versatility in paleontology showed how difficult it was becoming for a person to master this one of the biologic sciences. Material was being accumulated in all parts of the world, and results were being published in many languages and in almost unlimited places. A work was needed to orient this great accumulation. In part, this had been accomplished by Bronn in his Lethaea Geognostica, and in the text-books of Geinitz, Giebel, Quenstedt, Pictet, d'Orbigny, Owen, and Nicholson. Some of these works, however, had become antiquated, and none did justice to the growing science of paleontology from the point of view of the paleontologist. Zittel therefore undertook to orient all the material into one work, which should not only be an aid to all expert paleontologists, but should also form a basis of the science. From 1876 to 1893 he labored on the animal fossils, while the paleobotanical part was undertaken by his friend, W. Ph. Schimper, of Strassburg, and after the latter's death, by A. Schenk, of Leipzig. Zittel thus gave to the scientific world his greatest and most distinguished work, his Handbuch der Palaeontologie. This stupendous undertaking, which resulted in seventeen years of continuous search and deliberation, is published in 6 volumes, 4 of which are Zittel's, containing 3,357 pages and 2,976 figures. It is the Encyclopedia of Paleontology and the Dictionary of Extinct Genera of Plants and Animals, including their classification and geological duration. Branco has justly said that it is the "rescuing deed" in paleontology. Later the handbook was translated through the joint work of seven savants, headed by Charles Barrois. In 1895 Zittel rewrote and condensed his great work into one volume—the Grundzüge der Talæontologie (Talæozoologie), which has since been translated into English, under the leadership of one of Zittel's American students, Charles R. Eastman.

Osborn has stated in Science: "It is probably not an exaggeration to say that he did more for the promotion and diffusion of paleontology than any other single man who lived during the nineteenth century. While not gifted with genius, he possessed extraordinary judgment, critical capacity, and untiring industry."

While Zittel, since 1868, worked in paleontology along the lines of evolution, he never came to be a strong adherent of the neo-Lamarckian school. In fact, the development of the individual (ontogeny) did not seem to him to be reliable evidence as indicating the phylogeny of the stock and thus leading to a natural classification of organisms. The teachings of Cope and Hyatt did not take a strong hold on him, and we see in the second edition of his

Grundzüge, published shortly after his death, that he adopted none of the philosophic work of the collaborators in the English translation of the first edition. In this connection, A. S. Woodward has stated in Nature, "His last essay of general interest was an address on Paleontology and the biogenetic law." This address "was almost the only occasion in which Professor von Zittel ventured to express any opinions on the philosophy of biology or the solution of fundamental problems. * * * Indeed, scarcely any of his work can be regarded as suggesting important novel points of view."

In 1844 the Munich paleontologic collections began with Andreas Wagner as first curator, followed by Albert Oppel. These men brought together the collections of Graf Münster Häberlein Oberndorfer, Herzog von Leuchtenberg, Hohenegger, etc. Since then Zittel has enormously increased the Munich collection in all directions. Of ammonites, Zittel's Collection contains more than 2,600 forms, and this is but one of many examples that could be cited to show its great richness. "Thirty-seven and one-half years ago Zittel took charge of this collection. Toward its development he at first labored alone; later he had one and finally three assistants, and comparatively little pecuniary means were at his disposal. He left the Munich Paleontologic Museum the greatest in continental Europe, the most universal in existence, and scientifically one of the most famous and significant."

In 1846 was begun the great German paleontologic periodical, Palaeontographica, by Wilhelm Dunker and Hermann von Meyer. After the death of von Meyer, in 1869, Zittel became one of the editors, and since the death of Dunker, in 1885, he alone has directed this publication. Not less than 70 different monographs based on the Munich collections are by Zittel's students and owe their origin largely, if not entirely, to his stimulus. He "did not overshadow the plodding student by adding his own name as joint author" (Woodward).

Zittel devoted much of his time to teaching, regarding this work as important as that of investigation. In furtherance of his instruction he wrote his Handbuch and Grundzüge and created an additional help in his 73 paleontological and geological wall charts. Of paleontologic students who have studied in Zittel's School not less than 110 are recorded in the Album of the Paleontological Institute. His students are to be found in all European countries and in the Far East and West. He never sought to influence them other than as strenuous seekers after the truth. Each student of Zittel's could and must develop himself according to his own inclination and nature, free from all theoretic influence and from all narrow, prescribed limits of investigation. In but one direction did Zittel force his stu-

dents—to earnest work, to careful deliberation, to honest endeavor. This school of Zittel's still exists—large, widespread, and active in all fields of paleontology, emulating the example of its master. And this school has become the clear shining jewel in the crown of honor of this great man.

"Professor von Zittel naturally received numerous honors. Many years ago he became a privy councilor, and from 1899 until his death he was president of the Royal Bavarian Academy of Sciences. He was elected a foreign member of the Geological Society of London in 1889, and received the Wollaston medal in 1894. He was made a foreign associate of the United States National Academy of Sciences in 1899, and a correspondent of the Paris Academy in 1900. His greatest joy was the ardent friendship with which he was honored by his former pupils, scattered through nearly all the civilized nations of the globe" (Woodward).

One monument Karl Alfred von Zittel has erected for himself in his works, and another he has built, which has its foundation in the hearts of his students and friends—eternal love and honor.

DR. CARL GEGENBAUER.

CARL GEGENBAUR.[a]

By Oscar Hertwig.

Of the great naturalists who have by their works given to the nineteenth century its characteristic impress, another has been taken from our midst, the recognized leader in the domain of comparative anatomy of the vertebrates, the director of the morphological school which has developed in Germany under his influence.

Carl Gegenbaur died on June 14, 1903, in Heidelberg, in his seventy-seventh year, having some years previously relinquished his active duties as professor of human anatomy on account of continued illness. By his death the world has lost a peculiarly forceful and striking scientific personality.

At a time when the tendency to specialize was rapidly advancing, when through improved apparatus an almost inconceivable mass of new facts was being added to our knowledge, and when particularly the application of the microscope was completely revolutionizing many pursuits, Gegenbaur was especially interested in its application to anatomical science and in gathering together all known data and formulating certain general laws concerning the structure of animals. For this purpose he adopted methods of comparison which had already been employed by Cuvier, Johannes Müller, and others with great success. It was his aim, by a critical correlation of isolated facts, to elevate descriptive anatomy to the importance of a distinct science, which in contradistinction with physiology he was pleased to call morphology.

Unlike many others, Gegenbaur throughout his life attached more importance to methodical, systematic research than to isolated observations, however significant. The value and importance of the comparative method is particularly emphasized in the new Morphologisches Jahrbuch (Morphological Yearbook), founded by him in 1875. "The comparative method," it states, "depends essentially on critical analysis, and constitutes a synthetic process by which the results of critical treatment are brought together. This is to a large extent peculiar to the branch of science founded by him, since the

[a] Translated by J. Louis Willige, from Deutsche Medicinische Wochenschrift, Leipzig, XXIX Jahrgang, No. 29, July 16, 1903, pages 525, 526.

method can be dispensed with in other scientific researches. In itself comparative anatomy is only the development of methodical comparison. To this end anatomy offers an experimental basis. Therefore the significance of the method goes hand in hand with the ability to apply it as rigorously as possible. This is accomplished by taking into consideration all characteristics and their logical value. If this be not done, the method is uncritical and therefore unscientific."

Gegenbaur often discussed this matter, and stated in the introduction to his most important treatise, "The Cranial Skeleton of Selachians" (German), that in this critical examination and valuation of anatomical facts there was little in harmony with many other contemporary endeavors, which not only assumed the acceptance of isolated occurrences as scientific proofs, but also regarded every synthetical process of reasoning as erroneous.

At the time, this complaint may have had a certain warrant, for during the last three decades the value of the comparative anatomical method has not only been universally recognized, but it has also been applied in many directions in anatomical and embryological researches.

The series of comprehensive monographs published by Gegenbaur from 1864 to 1892 constitutes the foundation for a critical comparative anatomical method based on an immense amount of material. The most important of these, beyond question, is the monograph on the Cranial Skeleton of the Selachians, published in 1872, a treatise on our knowledge of the relationships of the schools of the vertebrates. The well-known vertebral theory advanced by Oken and Goethe, which was no longer defensible in its earlier form, is here revised and enlarged into a comprehensive segment theory concerning the head of the vertebrate applicable to different organic systems.

In a similar manner Gegenbaur worked out from the beginning almost the entire morphology of the vertebrate skeleton, in his Observations on the Comparative Anatomy of the Vertebrate Columns in Amphibians and Reptiles (1862), in his paper on Carpus and Tarsus (1864), on the Shoulder Girdle (1865), and on the Occipital Region of Fishes (1887). He had mastered also, as no other naturalist, the material relating to the subject of vertebrate morphology, and he imparted this knowledge in many unsurpassed text-books prepared and published by him; in his Elements of Comparative Anatomy, which first appeared in 1859, of which a second edition was issued in 1870, and which was later published in a condensed form, in 1874, as the Fundamental Principles of Comparative Anatomy (second edition, 1878): and finally, in his most important text-book, which embraced his further studies for ten years and rep-

resented a compendium of his life's researches, the Comparative Anatomy of the Vertebrates as Compared with the Invertebrates. Of this great work, which Gegenbaur had the pleasure of seeing completed in the closing years of his life, the first volume appeared in 1898, and the second in 1901, only two years before his death.

But Gegenbaur was not only a successful naturalist; he was also, until the time of his death, an ardent teacher of human anatomy, and was very popular with his pupils. This afforded him opportunity also to communicate the fruits of his scientific endeavors for the advancement of anatomical study. There was such a demand for his text-book of human anatomy that, published in 1883, it had already reached its sixth edition in 1896. Convinced of the high didactic value of the genetic method, he endeavored with its assistance to add to the interest of the study of the human body and make many of its relationships better understood. He desired, as set forth by him in the fourth edition, "through its application to anatomical study to illuminate it." "Teaching means unfolding," as he tersely adds.

Although Gegenbaur did not possess the brilliant style of a Hyrtl, and although his descriptions were often tedious and sometimes difficult to comprehend, his text-book, on account of the substantial nature of its contents, immediately obtained a wide circulation among students, as is best attested by the rapidly appearing successive editions.

The biography of so distinguished a personality as Gegenbaur is always of interest to his contemporaries and to posterity, and there will doubtless be a number of biographical notices relating principally to his scientific accomplishments. Gegenbaur himself has given us, however, a small pamphlet with the title "Erlebtes und Erstrebtes" (Life and Strife), a concise autobiography, the preparation of which gives evidence of approaching feebleness and retirement from active service of the great savant, who no longer possessed his accustomed vigor.

Carl Gegenbaur was born in Würzburg, on August 21, 1826, and was the son of an official of good position. In consequence of various assignments of his father, he spent the earlier years of his youth in Weissenburg in Middle Franconia, and later in Arnstein in the Rhön Mountains. Here in rural surroundings was developed the foundation for his deep interest in nature, which was always a prominent characteristic.

Gegenbaur secured his preparatory training in Würzburg, where he graduated in 1845. In his biography he characterizes classic literature as "the true friend" of his life's career, since he was then, as always, a decided opponent of the movement for reform by the curtailing of classical studies.

At the age of 19 Gegenbaur entered upon the study of medicine and natural science at the University of Würzburg, somewhat against the wishes of his parents, though with the idea already conceived of later becoming a naturalist. It was fortunate for him that just at the time that he took up his studies, Würzburg had its most brilliant era in medical science. Kölliker and Virchow, two world-renowned men of science, were there, in their prime, as were also such excellent assistants as Leydig and Heinrich Müller.

After attaining the doctor's degree (April 15, 1851), for which he competed with Kölliker, and after completing his medical studies, Gegenbaur could not make up his mind to enter upon the practice of medicine, although he had served for a few semesters as assistant to his friend Friedreich on the resident staff of the Julius hospital. It was his ardent desire to become a naturalist and to enter upon a university career. Before he installed himself as private instructor, however, he experienced what he himself terms in his autobiography, a "period of wandering years." He journeyed through North Germany, where in Berlin he made the acquaintance of Johannes Müller. He pursued hurriedly for some weeks a study of the marine animals of Helgoland, and then embarked on an important scientific journey to Italy and Sicily, in which he was encouraged by Kölliker, who himself was undertaking with Heinrich Müller certain zoological investigations in Messina. After Switzerland and Italy had been traversed, Gegenbaur arrived with his friends in Messina, and occupied the fall and winter months in a zoological study of Messina's wonderful sea fauna. A journey through Sicily, followed by prolonged stays in Naples, Rome, and northern Italy, brought the "wandering years" to a close, which period, according to his own statement, constitutes an important epoch in the life of the great savant.

In 1854 Gegenbaur was installed in Würzburg as private instructor of the medical faculty, and taught for three sessions the subject of zoology.

From here he was called as early as 1856 as extraordinary professor to Jena, as successor to Oscar Schmidt, and as soon thereafter the famous anatomist Huschke died, he succeeded to the latter's position as regular professor of human anatomy in the medical faculty, which position he occupied until his call to Heidelberg in 1873. "Jena," Gegenbaur states in his autobiography, "was for me in every respect a high school, in which I received knowledge in many directions, and everything which I have later accomplished had there its origin and gives me reason for lasting thanks. I regard it as most fortunate for me to have remained for so long a time in Jena in my youth, the influence of which stay is indelibly impressed upon me."

On the recommendation of Gegenbaur, Ernst Haeckel was also appointed a private instructor in Jena. Between these two naturalists, working along the same lines, each in his own way as an energetic promoter of Darwin's new doctrine of evolution, there grew a firm friendship, which is testified to in glowing words by Haeckel in the introduction to his General Morphology.

In Jena the writer had the good fortune, as a student in the first medical semester, to become somewhat intimately acquainted with these two closely associated great naturalists, receiving instructions in anatomy and zoology, and being prepared by them in various ways for his later vocation, for which aid he will ever feel thankful.

Although united by many bonds to Jena, Gegenbaur, though only after long hesitation, accepted the call to Heidelberg as successor of Arnold (1873). "It carried him to the south, whence he had come." Other calls which followed later, to Amsterdam and to the newly-established university at Strassburg, were declined. He possessed, however, in Heidelberg everything that he could wish—a limited course of instruction in a magnificently equipped university, which in the more congenial southern part of Germany gave him leisure for uninterrupted progressive scientific work; and in his own home a happy family life which came from his marriage in Jena, after the death of his first wife, to the daughter of the anatomist Arnold.

The great naturalist was in all respects an admirable man, who quickly gained the love and respect of all with whom he became in any wise intimately associated. Resolute and uninfluenced by superficial things, he held firmly to that which he had by close scrutiny found to be true and just. Exacting with himself and others, he sought in close application to his work the happiness of life. Though evincing a warm and generous appreciation of the beautiful things in nature and art, he was naturally of a retiring disposition, inclined to avoid social gatherings, and only occasionally attended congresses and scientific meetings. Easily repelled by strangers, and at times perhaps harsh and inconsiderate, yet he possessed a sympathetic spirit, which often showed itself in most unexpected ways to those intimately known to him. For this reason, Gegenbaur's assistants were attached to him with rare love and devotion, and under his leadership felt themselves firmly bound to his school of morphology.

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